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BULLETINS

OF

AMERICAN PALEONTOLOGY

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VOL. XXI

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1934

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BULLETINS

OF

AMERICAN PALEONTOLOGY

Vol. 21

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No. 71

The Stratigraphy and Paleontology of Northwestern Pennsylvania
Part I : Stratigraphy

By Kenneth E. Caster

June 9, 1934

Paleontological Research Institution,
Ithaca, New York
U. S. A

This report on the stratigraphy of northwestern Pennsylvania includes in a revised form the subject matter of a thesis submitted to the Graduate School of Cornell University in partial fulfilment of the requirements of the degree of Doctor of Philosophy, February 1933.

ACKNOWLEDGMENTS

The completion of this work of revision and restudy has been possible largely through the fine cooperation which has been received from virtually every person of whom materials, information or advice have been requested. The full list of these cooperators would include practically all those living men who have had any part in the unfolding of the geologic history of northwestern Pennsylvania or adjacent areas. It would include also the present custodians of essentially all the extant collections of specimens and notes ever made in this area.

To Mr. Charles Butts especial gratitude is expressed for generous advice, the permission to examine his collections, and the use of geologic notes taken during his field work on the Salamanca and Olean quadrangles in New York. Dr. C. C. Adams of the New York State Museum, kindly permitted the removal for study at Cornell University of the entire fossil collection assembled by Mr. Butts during his studies of these quadrangles. There were more than twenty of these boxes of fossil specimens. Professor C. O. Dunbar graciously made possible the borrowing of a considerable part of the Beecher collection of fossils from the region about Warren, Pennsylvania, which are part of the collections of Yale University. Mr. H. A. Pilsbry, Curator of Mollusca, and Mr. C. M. B. Cadwalader, Director, of the Philadelphia Academy of Natural Sciences, also made possible a rather extensive loan from the Randall assemblage of Warren fossils in the collection of the Second Geological Survey of Pennsylvania on deposit at that institution. Mr. Edward Lindsey, secretary of the Warren Academy of Science, and Mr. W. M. Pressel, superintendent of the Warren High School, loaned valuable material from the Randall and Cobham[1] collections in their respective institutions. Mrs. Jessie Armstrong of Erie, Pennsylvania, very kindly loaned portions of her late husband's excellent collection of lower Conewango fossils and this loan was graciously continued by Professor Swinnerton of Antioch College after Mrs. Armstrong presented the collection to that school.

---

[1] F. A. Randall and Henry Cobham were assiduous fossil hunters and amateur geologists in Warren, Pennsylvania during the latter part of the Nineteenth Century. Their collections, together with those of Charles Beecher are the most valuable ever made from this region.

Messers G. H. Chadwick and Bradford Willard have read the manuscript of this report and made valued suggestions. It is a pleasure to be able additionally to fortify by field evidence several of the sagacious conclusions drawn by Mr. Chadwick in his antecedent work on some of the same problems.

The keenest pleasure of all is the privilege to express in this inadequate manner a little of my appreciation of the valued encouragement and assistance so gladly given by Professor G. D. Harris during the course of this investigation.

KENNETH E. CASTER

Laboratory of Paleontology
Cornell University
August 20, 1933.

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INTRODUCTION

The stratigraphic stint undertaken in this restudy is the exposition of the relationships of the Lower Mississipian and Uppermost Devonian strata in northwestern Pennsylvania, especially as surfacially developed[2].

The area under consideration contains the only typically marine expression of the Uppermost Devonian system known in the eastern United States. Here, furthermore, occur the oldest known marine Mississipian strata in eastern America. The relation of these two unique sequences has been a controversial point for three decades or longer.

Northwestern Pennsylvania almost completely embraces the sole area occupied by marine waters at the close of the Devonian in the eastern states. Here is written the closing chapter of the history of red bed encroachment in front of the "great Devonian (or Catskill) delta". Or at any rate, here is the sole area of preservation of a legible portion of the closing chapter.

When the study of the fossil faunas in the higher formations of the pre-Pennsylvania strata on the upper reaches of the Allegany River was first undertaken in 1929[3] no plans were laid for an extensive stratigraphic investigation. This phase of the work seemed completed. But as work progressed on the faunal studies the truth gradually materialized that it would be impossible to complete the faunal studies in a satisfactory manner prior to a very thorough-going restudy of the stratigraphy of the whole northwestern corner of Pennsylvania and the adjacent territory of New York and Ohio.

---

[2] The subsurface relationships in this area have been known to a far better degree than the surface relationships because of the economic necessity of the oil industry of northwestern Pennsylvania. The recent paper (1933) by C. R. Fettke on the subsurface correlation across northern Pennsylvania is a valued addition to this important field. G. H. Chadwick also has written a very clarifying report on the subsurface correlation of much the same area. Chadwick's report is now on file with the Pennsylvania Topographic and Geologic Survey.

[3] Preliminary report on the fossils published in 1930: Higher Fossil faunas of the upper Allegany (River). Bull. Amer. Pal., vol. 15, no. 58, pp. 140-316, 59 pls., 1930.

Much work had previously been done on the stratigraphy of this region by a cohort of workers. Few of these men had the time to investigate the problem sufficiently long to complete the study; whereas others covered the problems too hurriedly and fell into egregious error. The chief work on the area was that of the Second Pennsylvania Geological Survey. The County Reports of this Survey was too insular, too lacking in correlation, to make wide scale application possible. Too many sets of conflicting and overlapping nomenclature were inadvertantly proposed and too many conjectural correlations made on the assumption of "the parallelism of strata". As these disconcerting truths gradually impressed themselves upon the writer there was no course open but to undertake a careful study of the stratigraphy of the whole region with the hope of bringing about enough order to make a monographic treatment of the faunas possible.

When the preliminary report on the "Devono-Carboniferous" faunas of the upper Allegany River basin was completed in 1929 the work of stratigraphic revision began in earnest. Three seasons have subsequently been spent in the field.

This report is by no means stamped with finality; it is viewed rather as a commencement on a problem of far-reaching proportions. It is hoped that the observations herein recorded for the limited area encompassed will prove of use in tracing strata into adjoining territories. The chief objective of this report is to correlate the Upper Devonian and Lower Mississippian strata occurring in the northwestern counties of Pennsylvania and the adjoining counties of New York and Ohio. The counties partially or wholly studied are: of Pennsylvania, Erie, Crawford, Warren, McKean, eastern Potter, northern Mercer, northern Venango, northern Forest and Elk; of New York, the southern part of Chautauqua and Cattaraugus counties, and of Ohio, the northeastern counties. This is admittedly a large area to be dealt with even in this report. (See map in front.)

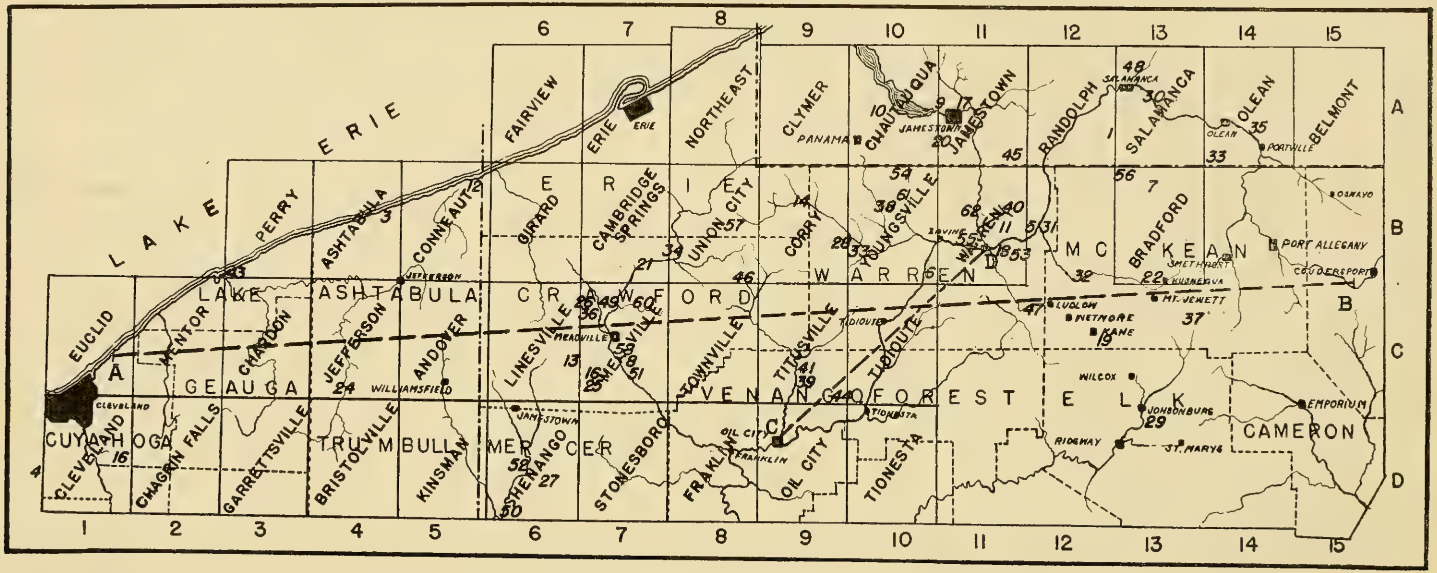
In this problem of exposition it is felt to be an odious duty to discuss in some detail the more recent and most quoted papers dealing with this region, for it is largely from these papers that current and commonly erroneous concepts of the age and stratigraphic relationships in northwestern Pennsylvania have been derived. This correction and amendation is done neither with personalities in mind nor in a spirit adversely critical, but solely in the interest of seeing the errors of too much haste corrected, and the true perspective presented. It is fully appreciated that parts of the present work quite possibly may be subjected to similar "vivisection" later on.

With recognition of the earnest though occasionally misguided endeavor of some of the earlier geologists who strove to interpret the relations of the rocks in northwestern Pennsylvania, such as James Hall, J. J. Stevenson and H. D. Rogers, the "heroic age" and its insufficiencies is left behind and the scene shifts to the latter part of the Nineteenth Century when the first truly substantial work on the geology of northwestern Pennsylvania was done.

Of the many workers who have contributed to the knowledge of the stratigraphy and structure of this region, commonly spoken of as the "Oil Region", none stands out to better advantage than J. F. Carll. He was probably more familiar with the subsurface geology of the Oil Region than any man since. He early recognized the importance of carefully recorded accounts of the oil well sections and has left a wealth of data in his reports of the Second Pennsylvania Geological Survey. Though many of his conclusions were discountenanced from the outset by men less familiar with the area, or less alert, it is pleasant to be able to reassert many of his conclusions and express appreciation for the tireless industry and keen perception of the man. Were it not for the many well logs which Carll collected it is doubtful whether the stratigraphic relationships in this region could be made known, so sparse and so thin are the surface exposures over most of the area. Carll, however, in common with all the early stratigraphic workers in the area, was markedly hindered by lack of knowledge of the fossil faunas, for therein lies the key.

Fig. 1.—Map of northeastern Ohio, northwestern Pannsylvania and southwestern New York, showing localities and section lines. Key to the numbered localities:

1. Allegany Park, N. Y. 12-13 A
2. Amity, O. 5 C
3. Ashtabula, O. 4 B
4. Berea, O. 0 D
5. Big Bend, Pa. 12 B
6. Bimber Run, Pa. 10 B
7. Bradford, Pa. 13 B
8. Byham School, 7 C
9. Chadakoin River, N. Y. 11 A
10. "Checker Schoolhouse," 10 A
11. Cobham Monument, Pa. 11 B
12. Conneaut, O. 5 B
13. Conneaut Outlet, 6 C
14. Cory, Pa. 9 B
15. Custards, Pa. 7 C
16. Cuyahoga, O. 1 D
17. Dexterville, N. Y. 11 A
18. Dutchmans Run, 11 B
19. East Kane, Pa. 12 C
20. Ellicott Tp., N. Y. 10 A
21. French Creek, 7 B-C
22. Gaffneys, Pa. 13 B
23. Garland, Pa. 10 B
24. Grand River, 4 C-D
25. Harvest Home, 7 C
26. Hayfield, Pa. 7 C
27. Hempfield, Tp., Pa. 6 D
28. Hosmer Run, 9-10 B
29. Johnsonburg quarry, 13 D
30. Kilbuck, N. Y. 13 A
31. Kinzua, Pa. 12 B
32. Kinzua Creek, 12 B
33. Knapp Creek, N. Y. 14 A
34. Leboeuf quarry, 8 B
35. Lillibridge Creek, 14 A
36. Littles Corner, Pa. 7 C
37. Marvin Creek, 13-14 C
38. Millers Cliff 10 B
39. Miller Farm, Pa. 9 C
40. North Warren, Pa. 11 B
41. Oil Lake, Pa. 9 C
42. Orangeville, Pa. 6 D
43. Painesville, O. 3 B
44. Pit Hole, 9 C
45. Popes Hollow, 11 A
46. Riceville, Pa. 8 B
47. Roystone, Pa. 12 C
48. Salamanca cgl. 13 A
49. Saegerstown, Pa. 7 C
50. Sharpsville, Pa. 6 D
51. Shaws, Pa. 7 C
52. Shenango, Pa. 6 D
53. Stone Hill, 11 B
54. Sugar Grove, Pa. 10 B
55. Tanners Hill, 11 B
56. Tunangwant Creek, 13 A
57. Union City, Pa. 8 B
58. West Mead Tp., Pa. 7 C
59. Wetmore, Pa. 12 C
60. Woodcock Tp. Pa. 7 C
61. Wrightsville, Pa. 10 B
62. Yankee Bush Hill, 11 B


LAKE ERIE
EUCLID
MENTOR
PERRY
ASHTABULA
CONNEAUT
FAIRVIEW
ERIE
NORTHEAST
CLYMER
CHAUTAUQUA
JAMESTOWN
RANDOLPH
SALAMANCA
OLEAN
BELMONT
CLEVELAND
CHAGRIN FALLS
CHARDON
GARRETTSVILLE
JEFFERSON
BRISTOLVILLE
ANDOVER
KINSMAN
GIRARD
CAMBRIDGE SPRINGS
UNION CITY
CORRY
YOUNGSVILLE
WARREN
BRADFORD
LINESVILLE
MEADVILLE
TOWNVILLE
TITUSVILLE
TIDIOUTE
SHENANGO
STONESBORO
FRANKLIN
OIL CITY
TIONESTA
CUYAHOGA
LAKE
GEAUGA
ASHTABULA
TRUMBULL
MERCER
ERIE
CRAWFORD
VENANGO
FOREST
WARREN
ELK
MC KEAN
CAMERON
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JAMESTOWN
PANAMA
IRVINE
LUDLOW
WETMORE
KANE
WILCOX
RIDGWAY
JOHNSONBURG
ST. MARYS
EMPORIUM
MT. JEWETT
KUSHEQUA
SMETHPORT
PORT ALLEGANY
COUDERSPORT
PORTVILLE
OSWAYO
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FIGURE 1

The Pennsylvania counties adjoining the Ohio line in the north were studied by I. C. White, who made a very careful survey of the area and proposed the names for many stratigraphic units as will be shown under the discussions of the various formations and members. His greatest work in this part of Pennsylvania was on the surface occurrence of the strata Carll recorded in his oil well sections. White's addiction, along with most of the other members of the Survey, to the theory of the parallelism of strata occasionally led him astray. His penchant for correlation at too long range has been the cause of several erroneous stratigraphic conclusions in the pleateau province which have stood for half a century. It is possible that the rather autocratic director of the Survey, J. P. Lesley, implanted his views in the reports through the pen but against the judgment of White, as he definitely did in the case of Carll. White's many surface sections in Erie, Crawford, Venango, Mercer, Butler, and adjoining counties have been found to be for the most part trustworthy in the expression of relationships, although they are occasionally erroneous in nomenclature.

In McKean County the Survey report was prepared by Charles Ashburner. In this report it is unfortunate for the stratigrapher that the care and attention lavished on the supra-Olean beds was not at least occasionally distributed over the whole exposed geologic section. The economic import of the coal fields was of course, the guiding influence. On the whole though, the report is very useful and the observations reliable though difficult to use because of their diffusion through the report. The same high standard of the McKean County report was maintained in the Elk and Forest Counties report by Ashburner in 1885 and in the Cameron County report in the same volume by A. W. Sheaffer. However, the stratigraphic knowledge to be gleaned from this last volume of reports is not very great.

In reviewing past workers who made substantial contributions to the geologic knowledge of the region, the name of F. A. Randall, a pharmacist of Warren, Pennsylvania, looms large. To him and his youthful assistant, who was later to become Professor Charles Beecher of Yale, geologists are indebted for assiduous paleontologic collecting and careful stratigraphic sectioning in and about Warren County.

Stratigraphic study came to a temporary halt in Pennsylvania after the close of the Second Geological Survey. In 1903 L. C. Glenn published the results of his investigation of the geology of the Olean and Salamanca quadrangles of New York. In this work the problem of Devonian and Mississippian boundary line came into the foreground. Practically all subsequent work in northwestern Pennsylvania, northeastern Ohio and southwestern New York has gyrated about this question. G. H. Girty and C. S. Prosser entered the controversy from the Ohio side, and Charles Butts, who had assisted Glenn in his work on the Salamanca and Olean quadrangles, made modified application of the combined conclusions of Glenn and Girty to the Upper Devonian and Mississippian formations in northwestern Pennsylvania, especially in the area surrounding Warren. All of these men of the new era of geologic interest, made very valuable contributions to a fuller knowledge of the "Oil Region".

In the years 1916-1917, there appeared the last of important stratigraphic contributions on this area which were based on detailed field work. These were the papers of W. A. Verwiebe on the Berea formation of Ohio and Pennsylvania (1916), the correlation of the Mississippian of Ohio and Pennsylvania (1917) and the correlation of the Devonian shales of Ohio and Pennsylvania (1917). These are creditable attempts but suffer from many miscorrelations largely due to neglect of faunal evidence.

Temporarily passing over the indirect contributions of Ulrich, Kindle, Hyde and Prosser and several others who centered their activity in Ohio, and whose contributions are discussed elsewhere in this report, several fruitless years passed before interest in this region was again renewed. The brief but poignant papers of G. H. Chadwick mark the next step in the investigation of the region. As a development out of his work on the Portage-Chemung beds in New York State and investigation of the Chagrin rocks of Ohio he drew up a diagram of the presumable correlation of the Upper Devonian formations of New York, Ohio and Pennsylvania. Although these correlations were made largely from literature, they have proved in the course of this study to be largely commensurate to the field facts.

For reference to the contributions of additional workers than those cited above, notations are made in proper places in the text and a comprehensive bibliography is given at the end of the paper.

STRATIGRAPHIC AND CHRONOLOGIC NOMENCLATURE

In this paper the rules of the International Geological Congress Commission of 1886 are adhered to in so far as they lead themselves to a better explanation of the stratigraphic and time relations in western Pennsylvania. The difficulties of this system or any highly systematic and artificial system for explaining natural phenomena are the difficulties of trying to make plastic nature conform to rigid rule. The system of chronologic and stratigraphic nomenclature which is here being used is by no means entirely satisfactory, nor will any system be satisfactory until an attempt is made to shape the nomenclature to the rocks, not *vice versa.*

The international system of nomenclature provides[4] for five progressively smaller stratigraphic categories. These are, from largest to smallest: group, system, series, stage, sub-stage, and "beds". The equivalents in the chronologic scale are: era, period, epoch, age and phase. The United States Geological Survey has never entirely adopted the international system of stratigraphic nomenclature. The Survey "group", for example, corresponds to the international "stage". For stability some one system ought universally to be followed, as in the systematic nomenclature of the biologic sciences.

A recent[5] attempt at standardization has been made by representatives of American geological societies who appreciate the need of a set of nomenclatorial rules in stratigraphic science. The parallel lists below show how the international system compares with the recently outlined American system. Neither is entirely satisfactory. Certain refinements of both systems taken together seem to be better adapted to the exposition of natural relationships. In the interest of priority and clarity certain modifications of the recently outlined system seem advisable.

---

[4] G. Dewalque, Report of the Secretary of the Committee for the Uniformity of the Nomenclature. Proc. International Geologic Congress, Third (Berlin) session, 1886, pp. 49-72. (Published by the American Committee.)

[5] Classification and nomenclature of rock units, by a representative group of American geologists. Geol. Soc. Amer., Bull., vol. 44, pp. 423-459, 1933.

International system	*American system* 1933
Group	No coordinate with Era[6]
System	System
Series	Series
Stage	Group
Formation (sub-stage)	Formation
Member (beds)	Member, lentil, tongue
	Bed, stratum, layer
Zone	Zone

The international system of nomenclature is weakest for divisions of strata below "stage". In the present report stratigraphic "stages" are recognized, largely because the alternative term "group" is already used as a correlate of era in the international system. Because of the premiscuous usage of the term "substage" and even more indefinite usage of the equivalent though secondary international category "formation" a more specific term for the major stratigraphic division under stage is necessary. It is high time than an attempt was made to either discard or specificize the term "formation". Probably the most satisfactory obviation of the difficulty would be new names for the various geologic connotations of the term.

For "cyclic formations" J. M. Weller[7] has proposed the term "cyclothem". This is an excellent gesture. There may be some justifiable doubt, however, if these "cyclic formations" may not in some instances actually fall into the rank of the international "stage". By definition the cyclothem is "to rank exactly as a formation in stratigraphic classification". By this is meant, presumably, an American formation, about which there is no general consensus. It is suggested that when the cyclic nature of

[6] In view of the American deficiency of a stratigraphic correlate of era, R. C. Moore in his Historical Geology textbook, Macmillian, 1933, p. 54, proposes the term "sequence". Such a procedure is as regrettable as the early proposal of "formation", for both have long been used in a variety of ways in geologic literature. Moore also lists "stage" and "substage" as respective subdivisions of "age" rather than as stratigraphic subdivisions as they were originally intended.

[7] Correlation and extent of Pennsylvania cyclothems, by H. R. Wanless and J. M. Weller, Geol. Soc. Amer., Bull., vol. 43, p. 1003, (footnote by Weller), 1933.

strata which are major in importance under an International "stage" or an American "group" seems to be better explained by the term, cyclothem be used. It is obvious that not all major divisions of stages or groups are of a cyclic nature.

For the more ordinary, and perhaps more normal major subdivisions of a stage, that is, for non-cyclic, or not obviously cyclic units of genetically related strata the term *monothem** is proposed.

When natural conditions require their subdivision monothems are divisible into *members*. Members are stratigraphic elements of somewhat localized occurrence under the more usual conditions of sedimentation. Members are further divisible into beds and zones of lithologic or biologic distinction. Members also occasionally contain lenses of distinctive lithology. The conglomerates of the Upper Devonian and Lower Mississippian in northwestern Pennsylvania are examples of lenses in the midst of members. However, some of these cited conglomerates are of sufficient extent to merit being termed members, as is done in this report.

Better to show relationship within monothems it is sometimes an aid to expression of clarity as well as convenient to bracket several intimately related members together into what are here called *formational suites* or in common speech "suites". Such suites are therefore categories intermediate in scale between monothems and members. This usage is illustrated by the grouping in the stratigraphic portion of this paper of the upper and lower Salamanca conglomerates and the intervening thin shale bed into the "Salamanca suite". It is obvious that this term, like Weller's cyclothem cannot be regularly employed in stratigraphic nomenclature. Natural conditions and relationships will dictate the usage of each.

---

*From the Greek **monos** meaning one or primal, and **thema** meaning something which is laid down.

FACIES

NOMENCLATURE

The Upper Devonian rocks of New York, Pennsylvania and Ohio are especially characterized by an almost perfect development of facies. The contemporaneously deposited facies of almost any Upper Devonian formation grade from deltaic red beds in the east, proximal to the Catskill delta, through normal marine clastics in the central area and eventually pass into carbonaceous shales deposited in an open or perhaps Sargasso-like sea in the west. In the past, when the facies relationships were less well recognized, in almost every instance the typical development of each of the many coeval facies of a specific Upper Devonian formation was given a stratigraphic name. The discovery of the commonness of facies conditions necessitates the reference of many of the names to synonymy.

By strict priority the first name proposed for a geologic unit must stand. Unless facies are to be recognized by geographic names, as it would seem they should be, literally dozens of extremely useful, and thoroughly well established names must be given up. Such wholesale discard of nomenclature seems to be a little too progressive. As an alternative which will do homage to the yesterday and at the same time be a very usable system of nomenclature it is suggested that two facies denominations be recognized, which will bear geographic names. The largest of these facies categories will be known as a *magnafacies** and subdivisions of it will be known as *parvafacies**. Before defining these new terms at greater length it is necessary to outline the facies conditions in the Upper Devonian of New York, Pennsylvania and Ohio. The relation of the facies elements to the stratigraphic is shown in figure 2, below. The horizontal (virtually so) lines between stratigraphic units (stages, primarily considered) are termed *planes of contemporaneity* and the boundaries between the magnafacies, (parvafacies as well) are termed *facies planes* though, obviously, they are never sharp enough to be recognizable as a plane in any section. However, the total effect is planar.

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*From **magna,** Latin, meaning large and **facies,** thus "great facies"; and from **parva,** Latin, small, therefore, "small facies".

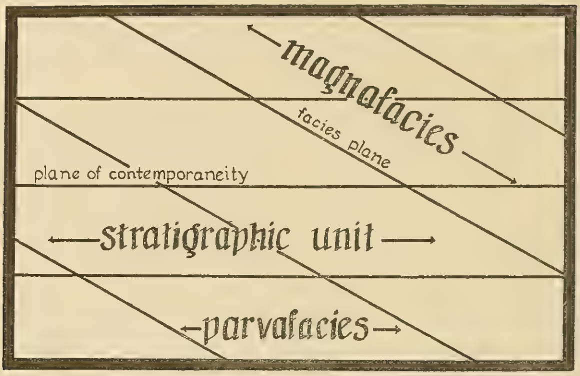

Fig. 2.—Facies components

FACIES RELATIONSHIPS

As an approach to the somewhat complex problem of the relationships of the various late Devonian facies across Pennsylvania, New York and into Ohio it is convenient briefly to review the chief conditions of deposition at that time. In North America the Upper Devonian epicontinental sea was centered in the West and Mid-West. An embayment of this sea extended eastward across southern New York and northeastward across Pennsylvania. The eastern border of this broad embayment in Middle Devonian time (upper Hamilton) was in the approximate vicinity of the present Catskill mountains and northern New Jersey[8]. Uplift of Appalachia in the east had begun somewhat previously. Several rivers flowed westward from the highlands of Appalachia and built up deltas at their mouths. As uplift of Appalachia was periodically renewed or continuously in progress the rivers underwent repeated rejuvenation, and the deltas at their mouths continuously built out toward the west and northwest. With the continental uplift there was also recession of the sea-arm from New York and Pennsylvania.

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[8] See: Joseph Barrell, The Upper Devonian delta of the Appalachain geosyncline, Am. Journ. Sci., vol. 36, pp. 429-472, 1913; Idem, vol. 37, pp. 87-109, 1914; G. H. Chadwick, Pocono Problem, (abstract), Geol. Soc. Amer., Bull., vol. 43, p. 273, 1932; Idem, Hamilton red beds in eastern New York, Science, vol. 77, pp. 86-87, 1933; Idem, Catskill as a geologic name, Am. Jour. Sci., vol. 26, pp. 479-484, 1933; G. A. Cooper, Stratigraphy of the Hamilton group of eastern New York, (abstract), Geol. Soc. Amer., Bull., vol. 44, pp. 200-201, 1933; Bradford Willard, The Hamilton group in eastern Pennsylvania, (abstract), Geol. Soc. Amer., Bull., vol. 44, p. 197, 1933; Idem, "Catskill" sedimentation in Pennsylvania, Geol. Soc. Amer., Bull., vol. 44, pp. 495-516, 1933.

At the same time that the deltaic facies were gradually encroaching westward with the passage of late Devonian time, so also were the respective off-shore facies encroaching toward the west. At the beginning of the encroachment of the Upper Devonian delta approximately half a dozen facies belts existed from the foothills of Appalachia out into the nearly thalassic marine area where the arm joined the main interior sea. These six facies (plus a continental, seventh facies) continued to exist during the remainder of the Devonian. These seven facies zones, or concentric belts, when given the dimension of time become complete lithic units, or true magnafacies. These seven facies formed during late Devonian time across New York and Pennsylvania are generally described in figure 3, below. It is natural that at any given horizon there is a horizontal graduation from one facies to the two adjoining, yet in the center of the typical development of each facies the characteristics are so distinctive that until recently stratigraphers have not recognized the contemporaneity of these several facies expressions.

For convenience, on figure 3 the seven major facies of late Devonian sedimentation in this area are designated by letters. These major facies have been designated magnafacies (see figure 3, below) and for them geographic names are essential, not so much for clarity, as for a way out of the dilemma of synonyms which have been proposed in the past for coeval facies. The portions of magnafacies included within formation boundaries must also have some designation to show their facies nature. Again, geographic names are conveniently available. Names which have figured much in literature, but which would necessarily fall into synonymy unless retained in a facies usage. These smaller facies units, the components of the magnafacies which are included between stage (or "formational") boundaries, are termed parvafacies. A stage is therefore comprised of contemporaneous laterally grading parvafacies of unlike lithology and distinct faunas, whereas a magnafacies is made up of varitemporaneous parvafacies of like lithology and closely related (mutated) faunas. See figure 3, below.

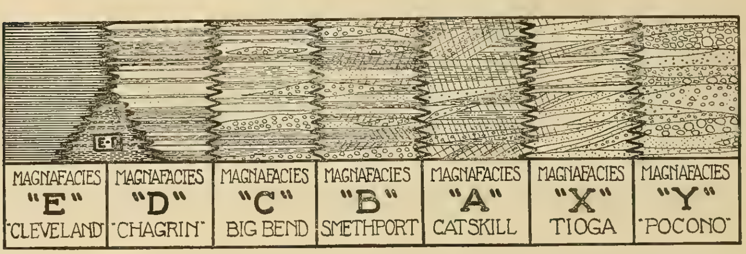

Fig. 3.—To show the general characteristics of the respective magnafacies developed in the Late Devonian embayment of New York, Pennsylvania and eastern Ohio. The wedge-shaped intercalation between magnafacies "D" and "E" is present in Middle and late Middle Devonian of New York and Pennsylvania, but in the Late Devonian is almost completely omitted.

The rocks of late Meso- and Neo-Devonian age in New York and Pennsylvania were deposited under conditions such that about seven definitely distinct magnafacies zones or provinces were developed. In Mesodevonian time there seem to have been eight magnafacies provinces, but this additional one was virtually omitted in later Devonian time. The seven magnafacies elements are recognizable in regular order in all the Upper Devonian stages represented in the Allegany plateau province of Pennsylvania and New York. The lithology of the respective magnafacies is well known and easily recognizable. The faunas, especially of the shoreward provinces, are less well known, especially as developed in eastern New York and Pennsylvania. Geographic names have been applied to the magnafacies elements of the New York and Pennsylvania Later Devonian embayment in accordance with the scheme mentioned above, and outlined in an abstract of a paper presented before the Geological Society in Chicago in December 1933 entitled "Application of a system of facies nomenclature to the Upper Devonian."

The most shoreward magnafacies of the Catskill delta seems to be represented by a coarse gray sandstone which usually grades into coarse conglomerates eastward, or shoreward. In appearance this magnafacies resembles the sandstones of the Pocono Mountains which have been called Pocono sandstone, and dated as Mississippian, in eastern Pennsylvania. The transformation of Upper Devonian beds into this Pocono-like magnafacies eastward makes one hesitant on this basis alone to assign a Mississippian age to the Pocono sandstone in its type area. For the time being the most eastern magnafacies of the late Devonian is being called "Pocono".*

Westward the coarse Pocono-like magnafacies (herein termed "Pocono" magnafacies) assumes a finer grained—less well sorted facies of brown (limonitic) weathering quartzitic micaceous sandstone usually replete with mud-balls and triturated cellulose. This facies occasionally contains brackish-water faunas. In the Tioga and Elkland area of Pennsylvania a parvafacies of this magnafacies which is now known to be of Chautauquan age was mistaken by M. Fuller[9] for the Oswayo formation at the top of the Conewango series. From this mistaken correlation the eastern development of this magnafacies has ever since been termed the Oswayo[10]. For this magnafacies the name *Tioga* is proposed. The Oswayo formation in the Olean, New York, area represents the Oswayo *sensu stricto* parvafacies expression of the Tioga magnafacies.

The misidentification of facies elements for stratigraphic elements in the case of the Tioga magnafacies illustrates the relationship of the respective parvafacies comprising a given magnafacies in this area influenced by the encroachment of the Catskill delta. As a normal phenomenon of sedimentation in an area subjacent to a constantly rejunevated upland, the boundary lines of the magnafacies climb the geologic column westward. This means that as the strand line encroached on the sea, so also each shoreward facies belt tended to migrate seaward. This phenomenon is illustrated in figure 4 below. The diagonal lines separating the magnafacies are termed *facies planes* and the horizontal lines which separate stages of sedimentation are termed *contemporaneity planes.*

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*The Pocono sandstone of eastern Pennsylvania is quite possibly much older than the so-called Pocono in central and western Pennsylvania where the beds so assigned seem to be Mississippian in age. In this connection a statement made in Schuchert's and Dunbar's Historical Geology, Wiley, 1933, p. 227, to the effect that the Pocono sandstone of eastern Pennsylvania passes into marine Mississippian beds (Waverly) in Western Pennsylvania and eastern Ohio, therefore apparently definitely establishing the Mississippian age of the Pocono, is utterly unsubstantiated by the field facts known to date. Nowhere in western Pennsylvania do Waverly beds extend far enough east to grade into the Pocono. The true age of the Pocono is yet to be determined.

[9] Myron Fuller and W. C. Alden, Description of the Elkland and Tioga quadrangles, U. S. Geol. Surv., Atlas, Elkland-Tioga (no. 93), 1903.

[10] To cite a late example of this usage: Bradford Willard, Stratigraphy of the Tioga region, Topo. and Geol. Surv. of Pennsylvania, Bull. no. 102B, p. 11, 1931.

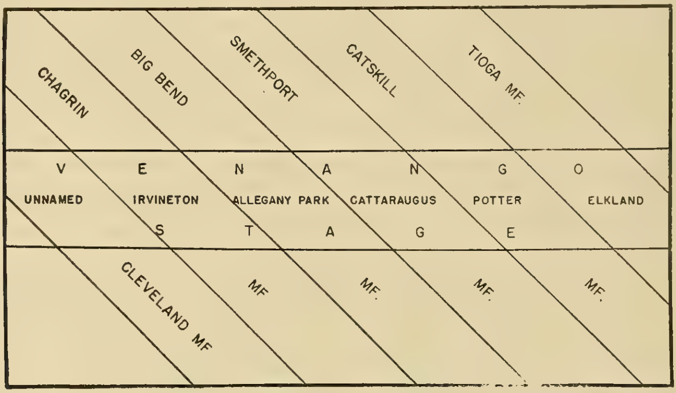

Fig. 4.—Nomenclature of the parvafacies constituting the Venango stage in northwestern Pennsylvania.

Until comparatively recent times concepts of stratigraphic relation in the late Devonian embayment were founded on the misconstruction of facies planes for planes of contemporaneity. The usual correlation, until very recent time, is illustrated by the identification of the Chautauquan parvafacies of the Tioga magnafacies as the stratigraphic equivalent of the Oswayo shale, the true position of which is some hundred or more feet above. In terms of the diagram this misidentification would correspond to placing as coeval the elements $A1=A2=A3$ etc.

This miscorrelation is comprehensible when it is recalled that in the eastern part of Pennsylvania and New York uplift was virtually continually operative during the late Devonian, and was subsequently intermittently operative. As a consequence the originally oblique facies planes tended more and more to approximate the position of the originally horizontal planes of contemporaneity. This is readily seen if figure 4 is rotated to accord with uplift in the east: that is, by elevating the right hand side of the diagram. The Upper Devonian strata were further uplifted and gently folded during the Appalachain revolution and subsequently re-elevated during the Mesozoic and Tertiary. Small wonder that in this country of somewhat sporadic outcrop the natural relation for long evaded the field worker.

To continue with the enumeration of the magnafacies, next west of the Tioga magnafacies and marginally interdigitated with it is the most publicized and perhaps best known magnafacies of the area: the Catskill red beds. The Catskill magnafacies is predominantly composed of red and green sandstones and shales which in places give way to coarse, conglomeratic sandstones of red or green color. Cross bedding, apparently both of a subaereal and deltaic nature are the rule. For the most part they are barren of organic life, but occasional fish and ostracoderms are found, presumably washed into brackish water to be preserved. On the western borderland of the province marine faunas occur in the midst of the red beds. Such a condition is shown at Lewis Run, McKean County, Pennsylvania, where a large marine fauna occurs in the bright red Catskill magnafacies. On the western border the red beds extend as long fingers, bar-like in development, into the westward-adjoining facies province.

The terminology of this red and green facies has been much discussed of late as a straitgraphic problem. the facies nature of the formation being overlooked. It was suggested by G. H. Chadwick early in 1933[11] that the name "Catskill' be restricted to a single red member of the total red bed development in the Catskill area. This on the basis of what he determined to be the original usage of the name "Catskill". Translated into present terminology, whereby it is recognized that the Catskill red beds are the continuously coeval eastern expression of other beds to the west, Chadwick proposed to limit the name Catskill to a single parvafacies of the red beds (of Enfield age). Such usage is hardly to be condoned because of the community of the understanding of the name Catskill as applicable to the whole red sequence. The terminology which Chadwick suggested for the red beds of the Catskill Mountain front was:

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[11] G. H. Chadwick, Hamilton red beds in eastern New York, Science, vol. 77, pp. 86-87, 1933.

7. Red beds of Bradfordian age[12] — Cattaraugus
6. Late Chautauquan (post Chemung) red beds — Blossburg
5. Wellsburg red beds (upper Chemung) — Montrose
4. Lower Chemung (Cayuta red beds) — Catawissa
3. Enfield (upper Portage) red beds — Catskill
2. Ithaca red beds (lower Portage) — Oneonta
1. Hamilton red beds (Middle Devonian) — Kiskatom

Bradford Willard[13] proposed later in the year that the formation to which Chadwick would limit the name Catskill might better be given another name. Willard proposed the name Kaaterskill to supplant the restricted usage of the name Catskill, thus making Catskill available for a more embracive usage.

In November, 1933, Chadwick[14] reviewed his previous paper of the year on the Catskill nomenclature and fell into line with Willard's suggestion to the extent of proposing another name for his previously delimited Catskill. In place of the usage of the name "Catskill" for the red phase of the Enfield he proposed the name *Katsberg* red beds. While the new name is more acceptable than Willard's inasmuch as the type section of Willard's Kaaterskill on Kaaterskill Clove appears to be in an exposure of Chadwick's Onteora red beds (Ithaca age), nevertheless Willard's name has priority. Chadwick now considers the Catskill as a red "formation". While this matter is not directly germane to the report at hand, the application of names to the various red elements in the Catskill Mountain section so perfectly illustrates the procedure advised for the rest of the facies of the Upper Devonian that it has been thus extensively dealt with. Chadwick's several names for red beds are parvafacies terms of the present scheme. The Catskill formation of Chadwick is a magnafacies.

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[12] So far as known, as this investigation will point out, there are no red beds of New York or Pennsylvania which are laterally traceable into the upper part of the old Bradfordian series (that is, the Cussewago series of this report). Furthermore, the Cattaraugus beds do not truly belong in the Catskill formation of Chadwick (magnafacies of this report). They represent, instead, a parvafacies of a westward-adjoining magnafacies of recognizable lithic and faunal distinction.

[13] B. Willard, Catskill sedimentation in Pennsylvania, Geol. Soc. Amer., Bull., vol. 44, pp. 495-516, 1933.

[14] G. H. Chadwick, Catskill as a geologic name, Am. Journ. Sci., vol. 26, pp. 479-484, 1933.

Westward the Catskill magnafacies gives way to purple and chocolate-weathering shales and sandstones in which occur as a normal feature, flatpebble (sometimes angular, but usually not markedly rounded) conglomerates, usually in the form of local lenses, but in the later parvafacies some carry over into the adjoining facies province to the west. It is proposed that this magnafacies be known by the name *Smethport,* from the town of Smethport, McKean County, Pennsylvania. The purple color of this magnafacies is partially a weathering phenomena, especially of the sandstones. The shales tend to become chocolate brown upon weathering.

The best known parvafacies of this magnafacies is the Cattaraugus parvafacies of the Olean, New York, area. This is coeval with the type parvafacies of the Venango stage west. Marine fossils are abundant in this magnafacies, in places constituting coquinites.

Seaward the Smethport magnafacies takes on an olivaceous to brownish color and a finer grain. In the next facies province, the strata, which are being termed *Big Bend* magnafacies, are of this color, and are an alternating sequence of shales and sandstones, with many lenses of conglomerate, along with several of the Smethport conglomerate elements which carry through. The portion of this magnafacies represented in the type area of the Venango stage is the best known parvafacies. An excellent section of the magnafacies is exposed along the Allegany River from Kinzua through Big Bend and on toward Warren, Pennsylvania. Wherefore the name Big Bend for the magnafacies. This magnafacies is a very important element in Upper Devonian stratigraphy of New York and Pennsylvania, for it is chiefly in this magnafacies that many of the type occurrences of Upper Devonian stages occur. The Ithaca beds at Ithaca, New York, and the Chemung beds in the vicinity of Elmira, New York, appear to be represented by parvafacies components of this magnafacies. Fossils are abundant in the Big Bend magnafacies. Apparently herein occurs one of the most characteristic faunal mutational series in the whole section of the late Devonian embayment.

That parvafacies of the Big Bend magnafacies which falls within the boundaries of the Venango stage, and which is therefore coeval with the Cattaraugus parvafacies of the Smethport magnafacies is herein termed the *Allegany Park* parvafacies, for the development in the New York State Park by this name south of Salamanca, New York.

The Big Bend magnafacies is transformed into an olivaceous, still fine grained shale and sandstone in the next seaward-adjoining province. Fissile olive shale ("brick shale") is the predominant element in this magnafacies in many sections. In this the more persistent conglomerates of the Big Bend magnafacies takes on a sandy facies and some even become calcareous. It is normally a blue gray shale and fine sandstone in the center of its development within its province. For this magnafacies the name *Chagrin* is being used. The Chagrin "formation" of Ohio is in reality a terrane, and this usage of the term for this important magnafacies which is almost if not quite as important as the Big Bend magnafacies has decided advantage over any other available name. The parvafacies of the Chagrin magnafacies within the Venango is being termed the *Irvineton* parvafacies from the village by this name on the Allegany River four miles west of Warren, Pennsylvania.

The Chagrin magnafacies in turn grows finer westward and in the earlier history of deltaic encroachment, when conditions were more stable, gave way to a bluish calcareous shale (typical Hamilton of Central New York, for example). Whereas, in Neodevonian time this blue calcareous (Hamiltonian) facies is almost completely omitted, except insofar as the Chagrin magnafacies assumed a more pronouncedly gray-blue color, and somewhat more calcareous nature in its extreme western limits.

The next western magnafacies is a black fissile shale which seems to have been the typical "open sea" deposit in Neodevonian time. For this westernmost magnafacies the name *Cleveland* is tentatively selected. The Cleveland shale is also a terrane embracing several stages, and the use of the name in this manner is clarifying.

ANALYSIS OF STRATIGRAPHIC SECTIONS IN TERMS OF FACIES

Under conditions such as existed in the Upper Devonian delta the shoreward facies progressively overlap the seaward facies. If this encroachment progressed at a constant rate then equidistant stratigraphic sections selected in the delta would tend to approximate the relationship indicated by figure 5, below. In this figure the letters correspond to the magnafacies of figure 3. All beds are considered of equal thickness, for the sake of clarity.

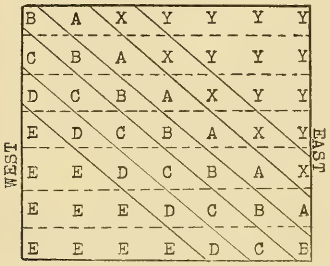


Fig. 5.—Idealistic relationship of the parvafacies within an area of regressional overlap. The letters correspond to the letters used in figure 3. However, the sections are wholly hypothetical.

It was interesting to compare actual sections of the Upper Devonian in northwestern Pennsylvania with the hypothetical scheme of figure 5. Sections were made along the meridians indicated in figure 6, below. These sections were analyzed for their facies elements. Again, the thickness is only partially considered, but it is only a minor element at best. When these sections are represented on the same plan as the hypothetical strata of figure 5 the result is rather astonishing similar as shown on figure 7.

PARVAFACIES OF THE VENANGO STAGE

The portion of the regressional overlap sequence of the Upper Devonian which is pertinent to this report falls within the Venango stage of the Conewango series (nomenclature of this report), and the uppermost portion of the Chautauquan series. Only the former is of primary importance in this investigation,

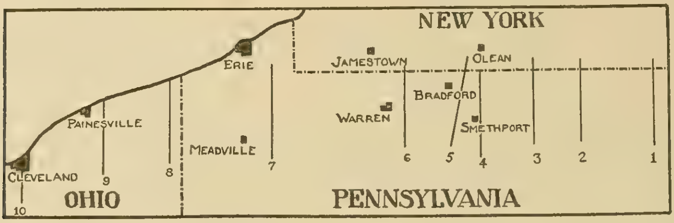
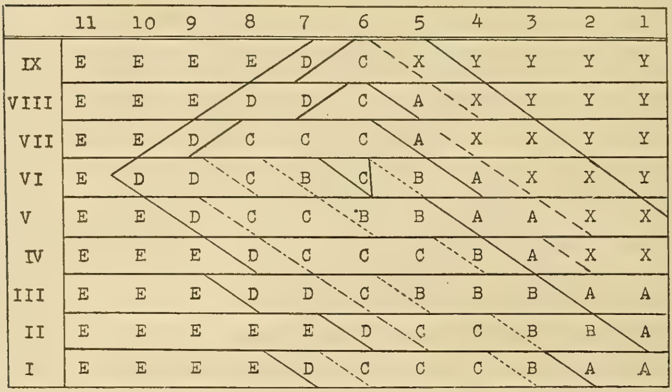


Fig. 6.—Showing the locations of the sections analyzed in the following diagrams of facies relationship.

for the Chautauquan rocks are largely subsurficially developed in northwestern Pennsylvania.

Within the Venango stage the respective parvafacies which are



	11	10	9	8	7	6	5	4	3	2	1
IX	E	E	E	E	D	C	X	Y	Y	Y	Y
VIII	E	E	E	D	D	C	A	X	Y	Y	Y
VII	E	E	D	C	C	C	A	X	X	Y	Y
VI	E	D	D	C	B	C	B	A	X	X	Y
V	E	E	D	C	C	B	B	A	A	X	X
IV	E	E	E	D	C	C	C	B	A	X	X
III	E	E	E	D	D	C	B	B	B	A	A
II	E	E	E	E	E	D	C	C	B	B	A
I	E	E	E	E	D	C	C	C	B	A	A

Fig. 7.—Analysis of representative stratigraphic sections in western Pennsylvania and eastern Ohio in terms of facies components. The letters refer to the designations made on figure 3, above. The meridians along which sections were selected are as follows: 1—east of Potter County, Pennsylvania; 2—eastern Potter County; 3—western Potter County; 4—eastern McKean County approximately on the meridian of Smethport; 5—section along a line from Olean, New York to Bradford, Pennsylvania; 6—section in the vicinity of Warren, Pennsylvania; 7—Meadville, Pennsylvania; 8—eastern Ohio to the state line; 9—the meridian of Painesville, Ohio; 10—the meridian of Cleveland, Ohio; 11—area immediately west of Cleveland, Ohio. The Roman numerals on the left refer to strata. Numbers from I through III represent strata of the upper Chautauqua series; IV through IX represent stages of the Conewango series. The apparent eastward overlap of the Cleveland shale magnafacies "E" in the west from VI through IX is interpreted as a reversion of facies provinces, a phenomenon explained below.

recognized at present from west to east are: a black shale parvafacies of the Cleveland magnafacies, as yet unnamed; the Irvineton parvafacies within the "Chagrin" magnafacies, described above; the Allegany Park parvafacies within the Big Bend magnafacies; the Cattaraugus parvafacies within the Smethport magnafacies; the red parvafacies of the Catskill magnafacies may very well be called the *Potter* parvafacies from the red development of the Venango stage in Potter County, Pennsylvania; the next eastern facies development of the Venango stage which is within the Tioga magnafacies might quite appropriately be known as the *Elkland* parvafacies from the area about Elkland, Pennsylvania. This parvafacies, as was previously mentioned, was originally mistaken for the eastern extension of the Oswayo shale. This nomenclature is shown in diagram by figure 7.

FACIES FAUNAS

The perfection of facies fauna development in the strata deposited in the Late Devonian embayment of New York and Pennsylvania will undoubtedly eventually render this region classic for the study of such phenomena. To date virtually no research has been done on these facies faunas. For the seaward part of the Uppermost Devonian stages in northwestern Pennsylvania the re-examination of the faunas has sufficiently progressed to make possible the prognostication of almost perfect correlation between the lithic and biologic expressions of the encroachment of the Catskill delta.

The work of H. S. Williams[16] on the so-called "recurrent" faunas well illustrates the westward migration of a fauna with its environment. The outstanding paleontologic contribution of modern times for eastern America will be the thorough restudy of all the Devonian faunas above the Oriskany sandstone in the Appalachain province. The horizontal and vertical range of species throughout this large portion of the geologic column is largely unknown. Furthermore, the breadth of specific criteria tends to negate any application of paleobiologic principles in this area and for the rocks of this time.

[16] H. S. Williams, Recurrent Tropidoleptus zones of the Upper Devonian in New York, U. S. Geol. Surv., Prof. Paper 79, 1913.

Preliminary examination of the highest faunas of the Devonian in western New York and Pennsylvania on the basis of facies relationships makes possible the promise that when such a study is completed for even the Uppermost Devonian the faunas will prove wholly dependable indices, and quite usable in the hands of a competent stratigrapher who will examine his fossils closely. On the basis of what is known of the Upper Devonian faunas of this embayment at present the fossils are useless, because species are reputed to have exceedingly wide vertical and horizontal distribution. One has only to consult stratigraphers who attempted to use the Chemung fauna for correlation purposes in the recent (1929-31) intensive examination of the gas-yielding area about Tioga, Pennsylvania, to verify the common consensus of the inefficiaceousness of these faunas in such work.

THE COMPONENTS OF FACIES FAUNAS

At this point it seems advisable to outline some of the practical and theoretical considerations necessary to a comprehension of the faunal affinities in the higher portion of the regressional overlap series of the Catskill delta. In figure 8, below, the chief elements are shown in diagram.

In a stratigraphic unit, that is, in contemporaneously formed strata, variants of specific forms occur, and must be recognized, as is obvious. The nomenclature of these variants is difficult. In the past they have largely been denominated "varieties", thus evading the detailed problem of relationship. If it were possible to examine the strata of succeeding ages one by one like the layers of an onion the problem would be simple. However, the limited extent of outcrop from the outset makes certainty of conclusion impossible. It seems nevertheless possible in the case of certain species occurring in the Devonian to differentiate between *ecological variants,* or *interfacial subspecies* and *geographical subspecies within a facies province.* As shown on the plan of contemporary faunal distribution in an embayment, a given species, for simplicity postulated as occurring for the first time in the embayment at the time of the diagram, is soon dispersed within the facies province which might be considered normal to it. Herein distance, or currents, or other contingencies, may act as a barrier and variants of subspecific rank result. These are the normal geographic subspecies of current biology. The species in some instances invades adjoining facies provinces or habitats

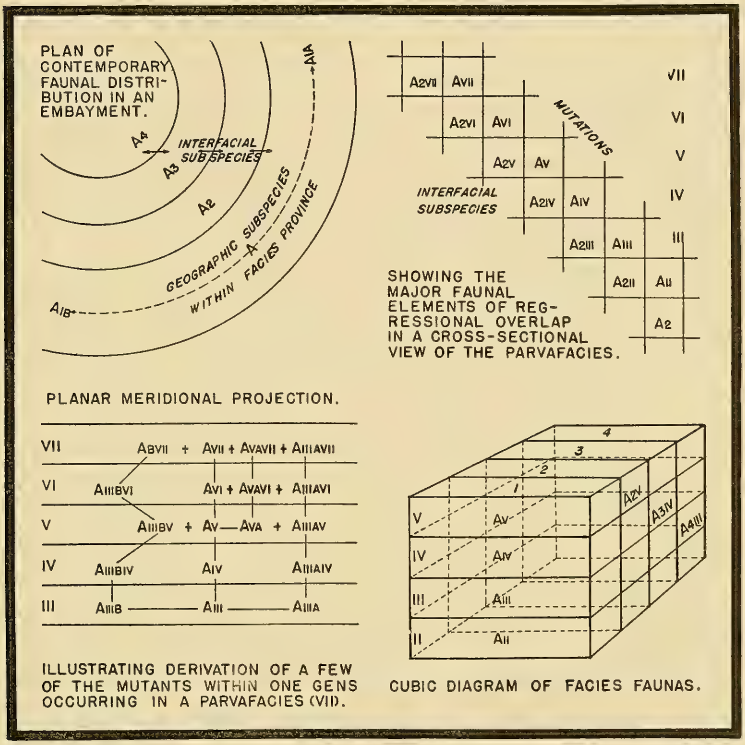

PLAN OF CONTEMPORARY FAUNAL DISTRIBUTION IN AN EMBAYMENT.
A4
A3
A2
INTERFACIAL SUBSPECIES
GEOGRAPHIC SUBSPECIES
WITHIN FACIES PROVINCE
A
AIA
AIB
PLANAR MERIDIONAL PROJECTION.
A2VII AVII
A2VI AVI
A2V AV
A2IV AIV
A2III AIII
A2II AII
A2
MUTATIONS
INTERFACIAL SUBSPECIES
VII
VI
V
IV
III
SHOWING THE MAJOR FAUNAL ELEMENTS OF REGRESSIONAL OVERLAP IN A CROSS-SECTIONAL VIEW OF THE PARVAFACIES.
VII ABVII + AVII + AVAVII + AIIIAVII
VI AIIIBVI AVI + AVAVI + AIIIAVI
V AIIIBV + AV—AVA + AIIIAV
IV AIIIBIV AIV AIIIAIV
III AIIIB AIII AIIIA
ILLUSTRATING DERIVATION OF A FEW OF THE MUTANTS WITHIN ONE GENS OCCURRING IN A PARVAFACIES (VII).
4
3
2
1
V
IV
III
II
AV
AIV
AIII
AII
A2V
A3IV
A4III
CUBIC DIAGRAM OF FACIES FAUNAS.

Fig. 8.—Diagrammatic representations of the components of facies faunas, and the general correlation between the lithic and faunal elements in an area of regressional overlap. For simplicity, only a few of the mutants within a gens are shown (AI,AII, etc.). Geographic subspecies are practically omitted.

and in them is occasionally materially altered. These ecologically altered subspecies sometimes occur geographically very close to the parent stock. If A represents the nascent species, so to speak, and Arabic numerals represent the facies belts, or habitats (when given the dimension of time: magnafacies) the lettering of the plan in figure 8 is clear. A2,A3,A4 represent interfacial subspecies of A, and AIA, and AIB are geographical subspecies.

In a condition of regressional overlap wherein habitat zone 1 creeps over habitat zone 2 etc., the subspecies tend, as a general rule, to mutate (Waagen sense) within their respective facies provinces, or magnafacies. This condition is represented by the second diagram of figure 8, which shows the major faunal elements of regressional overlap in a cross sectional view, so to speak. That is across the short axis of the parvafacies. In this diagram the Roman numerals refer to a succession of stratigraphic units, as shown on the right hand side of the diagram. When these numerals are appended to the Arabic subscript, denoting interfacies subspecies, it indicates the progressive series of mutants of the facies subspecies within a magnafacies.

If the faunal condition were as simple as these two diagrams would indicate, the problem of differentiation would be comparatively easy, but in each stratigraphic unit there are found in association with these elements already outlined, which might be thought of as the primary elements, supplimentary faunal elements the explanation of the relationship of which is exceedingly difficult, and hazardous. A simple, largely hypothecated, outline accounting for the coeval occurrence of several mutants within a single facies province is shown in the planar meridional projection of magnafacies 1 in the lower left corner of figure 8. The problem which this diagram illustrates is the explanation of the intermingled occurrence of several related mutants of the A stock in stratigraphic unit VII. For simplicity in the diagram only four of perhaps as many as a dozen (conditions of this sort are closely approximated in the upper part of the Conewango series in the case of *Spirifer disjunctus,*) mutants within the gens are shown. Naturally such schematic plans are largely hypothetical, due to the limited extent of outcrop along the major axis of any one parvafacies.

All of these diagrams of figure 8 are brought together in a cubic diagram in the lower right corner.

Of the several diagrams in figure 8 that showing the cross section of the parvafacies (upper right) most closely agrees with demonstrable field evidence, for the zone of outcrop across southern New York and northern Pennsylvania correlates with this drawing.

The several magnafacies shown on Figure 4 are characterized by "facies faunas". It is demonstrable that, for the most part, in latest Devonian time the faunas of the various facies expressions of a given formational unit were derived from faunas which had previously lived in an ecologic zone somewhat east of the occurrence in a given parvafacies. In the ordinary connotation a "facies fauna" is presumed to undergo little or no change for a long period of time, and as a result is insignificant in stratigraphic study. This common concept is presumably erroneous. Mutations take place even under constant ecologic conditions, but most stratigraphers are not willing to look closely enough at their "index fossils" to catch the significant variations. Hence the longe range and wide distribution of certain species of Upper Devonian Brachiopods, such as *Sprifier disjunctus* in the literature on the Upper Devonian. What has previously been called the species *S. disjunctus* is actually a whole group of species, subspecies and mutants, (that is, a "gens"[17]) which are perfectly recognizable when carefully studied. Heretofore they have never been subjected to sufficiently detailed study.

As the magnafacies "B" is traced up through the geologic column from the east toward the west it is found that the faunas of the respective parvafacies (as represented in the Chadakoin and Conewango, for example) are derived not from faunas in strata immediately below, but from parvafacies of the same magnafacies below and to the east. This is a general axiom, exceptions to which are naturally not uncommon. In terms of the figures, the fauna of parvafacies "B3" is derived from that of "B2" in the main, rather than from the underlying "C3". The chief portion of the "B3" fauna is composed of mutants (Waagen sense) of the "B2" fauna. In addition to the ecologically unilineal mutants there are also present in each successive parvafacies certain elements derived so far as known, as mutants from geographical sub-species of the northward or southward extention of a lower and more easterly antecedent parvafacies. There are also augmentations in certain parvafacies, the explanation of the origin of which is obscure. This is especially true of the Conewango parvafacies of the Irvineton magnafacies, wherein many totally new forms appear abruptly, without even a prenuncial trace to the east.

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[17] Term defined by C. L. Fenton, Studies of evolution in the genus Spirifer, Wagner Free Inst. of Sci., Publ., vol. 2, pp. 28-30, 1931.

The mutants, or authochthonous forms are very usable criteria for stratigraphic differentiation, but it is the foreign elements on which the major stratigraphic delimitations depend. The sudden appearance of several new genera in an area is a rather good indication of the letting down of a barrier or some rather fundamental geographic change such as would be a diastrophic basis for initiating a stratigraphic unit.

To recapitulate: the striking arguments for stratigraphic divisions are necessarily based on the new-comers in the normal facies expressions.

A problem of considerable importance to the paleontologist working in this area, and also of interest to the stratigrapher who must use scientific names for the fossils, is the adoption of a satisfactory nomenclature to express the faunal relationships which exist in these various facies patterns. The nomenclature of paleontology is necessarily two-dimensional. It embraces the horizonal and the vertical. In the horizontal dimension there are subspecies in the accepted geographical sense of zoological subspecies. However some differentiation should be made between the subspecies within a single facies zone and the subspecies of a given species which are characteristic of other contemporaneous facies zones. These are diagammatically shown on the figure above. Both are geographic, yet one is perhaps more directly environmentally influenced. The vertical component of the paleontologic species is taken care of by the categories described by Waagen as *mutants.* The successive faunas of the several parvafacies of any magnafacies which is fossiliferous are in the main, mutants out of antecedent, that is, stratigraphically lower and more easterly, parvafacies. These problems will be taken up in more detail in a subsequent faunal revision.

STRATIGRAPHIC CLASSIFICATION

MISSISSIPPIAN SYSTEM

General Classification

The original classification of the strata of northwestern Pennsylvania in the first really serious study of the area was that of I. C. White[18]. This was as follows:

- (Waverly beds)
  - Shenango group
    - Shenango shale
    - Shenango sandstone
  - Meadville group
    - Meadville
      - Meadville upper shale
      - Meadville upper limestone
      - Meadville lower shale
    - Sharpsville
      - Sharpsville upper sandstone
      - Meadville lower limestone
      - Sharpsville lower sandstone
    - Orangeville shale
  - Oil Lake group
    - Corry sandstone
    - Cussewago
      - Upper shale
      - Limestone
      - Middle shales and flags
      - Sandstone
    - Riceville shale

This classification is in many regards superior to any that has been subsequently proposed. It is essentially the outline form which is followed in the classification revision of this report, as will be seen by comparing the list above with the list at the beginning of the "Catalogue of Strata", below.

In 1910 Charles Schuchert proposed the following classification of the Mississippian in conjunction with his work on the paleogeography of North America[19].

Mississippian system (lower part)		
Osagian series		
Logan (Shenango shale of Pennsylvania)		
Black Hand (Shenango sandstones of Pennsylvania)		
Upper Cuyahoga (Meadville of Pennsylvania)	Pocono	
Kinderhookian series		
Middle Cuyahoga (Sharpsville of Pennsylvania)		
Lower Cuyahoga (Orangeville of Pennsylvania)		
Sunbury		
Berea (Cussewago and Corry of Pennsylvania)		
Bedford	Bradfordian	Knapp
		Oswayo
Cleveland		Cattaraugus

In this classification the old Waverly grouping of Newberry was omitted. In its stead the nomenclature of the Mississippi basin was applied. It is still doubtful if enough information of the faunas of the Ohio sequence is available to warrant this application of Mississippi valley nomenclature. Certainly the name "Waverly" should occur as a major division of the Mississippian.

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[18] Geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, pp. 66-116, 1881.

[19] Paleogeography of North America. Geol. Soc. Amer., Bull., vol. 20, p. 549, 1910.

The Pocono* occupies no such position as that shown in this scheme. The exact position of the Pocono, (that is, type Pocono, of Pocono Mountains: Pocono *s. s.*), is at present a controversal matter as explained below. It certainly is not as young as Schuchert indicates. The Kinderhook genera *Paraphorhynchus* and *Chonopectus* occur for the first time in western Pennsylvania and Ohio in the Corry sandstone, and not in the Bradfordian as Schuchert says[19a]. It is difficult to understand the basis for the series break placed between the Meadville and Sharpsville in western Pennsylvania and Ohio. These strata are virtually a continuous sequence, members of a single cycle. The faunas are not adequately known, but from collections at hand closer relationship than Schuchert's scheme would permit is indicated.

In the "Revision of the Paleozoic Systems" of 1911, E. O.

Note.—An interesting commentary on the age of the ''Pocono'' formation (or series) is the paper by G. H. Girty on the Pocono Fauna of the Broad Top Coal Field, Pennsylvania (U. S. Geol. Surv., Prof. Paper 150E, 1928.) Marine fossils from the Pocono formation are exceedingly rare and this sparse marine fauna is highly significant. On the basis of the fauna described in this paper the Broad Top Pocono beds might very well be of Devonian age, and so far as the sparse fauna would indicate could be of Oswayo age. Of course, larger faunas might prove these beds of true Mississippian age, but in the light of the grave doubts of Mississippian age of the true Pocono this fauna seemingly further substantiates the ground for doubt at least. The plants of the ''Pocono'' of south central Pennsylvania (Harrisburg area and west) seem to be of Mississippian stamp (Correspondence of Bradford Willard and David White, personal correspondence with Willard 1933). First, there is grave doubt if these ''Pocono'' beds are the correlates of the Broad Top ''Pocono'' and graver doubt if they correlate with the Pocono east of Mauch Chunk. But granting them as all correlates, the presence of unquestioned Mississippian types of plants does not disprove the coevality of these plant-bearing beds with marine Upper Devonian in northwestern Pennsylvania. The break between the Mississippian and the Devonian is so brief in time, so insignificant in disconformity, that it might almost be expected that the usually more precocious plants would have attained to Mississippian structural development during the closing stages of the Devonian in this Pennsylvania embayment.

[19a] **Idem, p. 551.**

Ulrich reclassifies[20] the Mississippian system of the Neopaleozoic as follows:

- (Mississippian system)
  - Tennesseean (sub-system)
    - Chesterian (series)
    - Meramecian (series)
  - Waverlyan (sub-system)
    - Osagian (series)
      - Keokuk
      - Late Burlington
      - Early Burlington
      - Fern Glen
    - Kinderhookian (series)
      - Chouteau
      - Hannibal
      - Glen Park
      - Louisiana
    - Chattanoogan (series)
      - Sunbury
      - Berea
      - Bedford
      - Cleveland
      - Olmstead
      - Huron

This classification recognizes the Waverlyan group of Newberry as a just classification of the Mississippian should. However, to elevate the Waverlyan to systemic rank as Ulrich does, seems to be a little too progressive, although the Waverlyan does compare favorably with the Devonian, for example, in thickness of strata and distinctness of faunas. The classification suggested in parentheses after Ulrich's names is the usage the writer would prefer. Ulrich included the beds from Hannibal through Keokuk inclusively as "Pocono" and Hannibal through Early Burlington inclusively as Cuyahoga formation.

In this classification, above, the identification of the Pocono as of Osagian-Kinderhook age is unsubstantiated, but the recognition of the relationship between the Berea and the Cussewago is very astute. Subsequent work by several students has cast some doubt on Ulrich's interpretation of the Sunbury-Huron black shale equivalence in Ohio and Pennsylvania in relation to the Chattanooga black shale to the south. Because of this doubt, and because more appropriate, and older available names for the basal Mississippian sequence, it would seem advisable to discontinue the use of the term "Chattanoogan" as a series of the Mississippian. The name "Oil Lake series" is more appropriate, both historically and geographically. A series name should be applied from a locality of normal sedimentation, which is usually considered as the area in which typical marine strata, clastics and limestones, occur, rather than in the black shale facies province of a formation.

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[20] Geol. Soc. Amer., Bull., vol. 22, p. 609, pl. 29, 1911.

Schuchert recognized the importance and historical significance of the Waverlyan in his textbook[21] wherein he modifies the classification of Ulrich is considering the Waverlyan as a subsystem. He does not definitely say that such is his classification, but his list, part of which is shown below, would imply this.

- Early Mississippian or Waverlyan
  - Osagian
    - Keokuk-Fort Payne-Logan
    - Burlington-Cuyahoga
    - Fern Glen
  - Kinderhookian
    - Chouteau
    - Rockford
    - Glen Park } Pocono
    - Louisiana
  - Chattanoogan
    - Sunbury
    - Berea
    - Bedford
    - Cleveland

The classification below, expresses the stratigraphic relationships of the major elements in the stratigraphy of the Mississippian of northeastern Ohio and northwestern Pennsylvania as understood at present:

- Mississippian system
  - Tennesseean sub-system (omitted)
  - Waverlyan sub-system
    - Osagian series (omitted)
    - Kinderhookian series
      - Chouteau
      - Hannibal } Sub-series?
      - Glen Park
      - Louisiana
    - Crawford subseries
      - Shenango stage
      - Meadville stage
    - Oil Lake series
      - Berea stage
      - Cussewago stage

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[21] Pirsson and Schuchert, Textbook of Geology. Part II, Charles Schuchert, Historical Geology. Table of Mississippian Formations, p. 335, 1924.

Obviously the Mississippian beds with which this report is concerned are those of the Crawford sub-series and the Oil Lake series. Both are well-marked sequences worthy of serial rank, as will be shown later.

Stratigraphic position and fossil faunas have been the chief criteria in adjudging the Mississippian age of these two series. The most important stratigraphic break occurs at the base of the Oil Lake series. This break is in the midst of that former grouping considered as of serial rank, the "Bradfordian". At the base of the Knapp shale (Kushequa shale of this report) there is a faunal and lithic break. It so happens that this hiatus is obscured because it is between two shales, the Oswayo and the Kushequa, of somewhat similar lithology, and in both of which are representatives of the same fossil gentes. Above the disconformity, however, in association with a fauna of Devonian stamp comprised largely of mutants there appear with abruptness the first representatives of undoubted Mississippian genera. It is unfortunate that the larger portion of this latter fauna is as yet undescribed.

There is no great break separating the Mississippian system from the Devonian, but the presence of a slight hiatus at the correct place in the sequence is sufficient to make the former "Devono-Carboniferous" or Bradfordian gradational series concept imposible. Nor is the situation remedied if the "Bradfordian series" is considered as wholly Devonian as some geologists now view it. There is no indistinguishable faunal admixture, as some have suggested, and sedimentation was not continuous. The Oil Lake series is characterized by a Mississippian faunal admixture in the midst of clear-cut *mutants* out of antecedent faunas of the Upper Devonian Conewango series. The Conewango series of the Upper Devonian has none of the Mississippian fossils of the Oil Lake, and few, if any, of the identical Devonian types.

The Oil Lake series and the Crawford sub-series are separated by a disconformity at the top of the Berea sandstone. The fauna of the Crawford series has none of the Devonian characteristics of the Oil Lake fauna. That is, it carries no mutants obviously derived from clearly antecedent and autochthonous Devonian species. In the Crawford series there are present a large number of genera and possibly a few species (or mutants of species) which occur in the Oil Lake series.

The Bradfordian "series"

For reasons outlined below, it appears that the stratigraphic grouping implied by the "Bradfordian series" in geologic tracts for the past thirty years is untenable. It develops that the Bradfordian series instead of embracing the Devono-Carboniferous transition beds in accordance with its original definition[22] or being wholly of Devonian age as was subsequently suggested[23] is really made up of a definite Devonian sequence which disconformably underlies a definite basal Mississippian sequence.

Among the earlier geologists to examine the rocks of the Allegany River basin and the shores of Lake Erie a conviction existed that in this area there is an "intimate association of the Devonian and Carboniferous systems"[24]. This concept flourished to the present. The basis for the concept lies in the somewhat loose identification of fossil species which has been made, and through failure to locate a nonconformity. In the absence of any revisionary work the original faunal lists are still the basis for stratigraphic argument. Faunal study in conjunction with this investigation indicates that many faunal identifications of the past are exceedingly untrustworthy. Complete faunal revision for the Upper Devonian and Lower Mississippian has been proved essential.

The strata below the Corry sandstone, and above the Chautauquan series in western Pennsylvania have proved a perplexing classificatory problem. For those rocks overlying what the New York State geologists were mistakenly terming the "Chemung" (Chadakoin) and underlying the Olean conglomerate (Pottsvillian) in New York and northwestern Pennsylvania several nomenclatorial systems have been proposed. Among the earlier writers all of the conglomerates in the region were called "Carboniferous conglomerates"[25]. Soon, however, the occurrence of several of these conglomerates in one section and obviously below the "coal measure conglomerate" (Olean) and in addition carrying a "Chemung" fauna, caused scepticism. Then came the period mentioned above, which was marked by the discomfiture of a conviction of an intimate association of Devonian and Mississippian strata.

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[22] G. H. Girty, Upper Paleozoic rocks in Ohio and northwestern Pennsylvania, (abstract). Science, vol. 19, pp. 24-25, 1904.

[23] Bailey Willis, Index to North American Stratigraphy. U. S. Geol. Surv., Prof. Paper 71, p. 421 (quotes letter from G. H. Girty), 1912.

[24] James Hall, Note on the intimate relations of the Chemung group and the Waverly sandstone in northwestern Pennsylvania and southwestern New York, (abstract). Am. Assoc. Adv. Sci., Proc., vol. 33, pp. 416-419, 1885.

[25] See, for example, James Hall, Survey of the fourth geological district. Nat. Hist. of New York, Part IV, Geology, 1843.

In 1900 the New York Geological Survey took up the study of the "Sub-Carboniferous" and Upper Devonian measures in the Olean and Salamanca quadrangles. L. C. Glenn, assisted by Myron Fuller and Charles Butts, studied these areas very carefully and came to varying conclusions. Glenn[26] proposed that the beds immediately above the "Chemung group" (that is above the Chadakoin), of modern classification which were characterized by reddish to purple color and contained conglomeratic lenses, be known as the Cattaraugus formation, of Devonian age. The Oswayo and Knapp formations above, he considered as sub-Carboniferous in age. Butts[27] who studied the fossils under J. M. Clarke, recognized the Cattaraugus as "Devono-Carboniferous". Clarke, in the same year, apparently abashed at this makeshift terminology decided[28] that for the New York Survey the Mississippian would be recognized as beginning with the Cattaraugus formation. It is so recognized by the State Geological Survey today.

In 1904, the year following the publication of the papers by Glenn, Butts and Clarke, G. H. Girty[22] proposed as a result of his studies in northwestern Pennsylvania and Ohio, that the sequence of rocks below the Olean conglomerate and above the "Chemung" (i.e., Chadakoin) in western New York, Pennsylvania and Ohio be known as the "Bradfordian series". This series he was as first prone to recognize as a gradational series between the Devonian and the Carboniferous. However, in a letter to Bailey Willis in 1910[23], Girty denied that he had originally considered the Bradfordian as other than of Devonian age, but in this letter he was more prone to consider the series as basal Carboniferous. In 1912, after further study of the supposedly equivalent black shales and of the Chagrin shales of Ohio, and with a somewhat preemptory dismissal of the faunal lists of Butts[27], Girty concluded[29] that the Bradfordian series should be considered as uppermost Devonian in age*. The New York State geologists still consider[30] the entire Bradfordian series as Mississippian, Girty's conclusions notwithstanding.

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[26] L. C. Glenn, Devonic and Carbonic formations of southwestern New York. N. Y. State Mus., Bull. 69, p. 971, 1903.

[27] Charles Butts, Fossil faunas of the Olean quadrangle. N. Y. State Mus., Bull. 69, pp. 990-995, 1903.

[28] J. M. Clarke, Construction of the Olean rock section. **Idem**, pp. 996-999, 1903.

The preceding paragraphs have indicated that the integrity of the "Bradfordian series" is more apparent than real. While it is perfectly conceivable that there might exist a perfect transitional series between the Mississippian and the Devonian, it is clear that if in the midst of such a supposedly homogeneous series there occurs a hiatus in deposition and also a critical faunal break, then the basis for the supposedly transitional series is no longer present. Such is the case of the "Bradfordian series". Natural relations are better explained by discontinuing the use of the term "Bradfordian" which is thus seen to carry an erroneous connotation.

The upper part of the original Bradfordian is the introductory sequence of the Oil Lake series of the Mississippian, and the lower part of the "series" is the closing phase of the Devonian, here called the *Conewango series*. The Conewango series exactly covers the strata which Butts had in mind when he proposed the name for a formation[31].

The Wilmarth correlation sheets of the United States Geological Survey[32] give a very graphic picture of the correlations and classification of the strata under discussion. However, there are certain minor errors in these charts such as would almost invariably creep in during the process of sifting the voluminous literature on this problem. The most serious miscorrelation is the placing of the Conewango formation above the Catskill, and both above the Venango oil sands. This error is obvious when the facies relationship is understood. Minor errors especially in the correlation of various conglomerates, are also to be expected.

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*The difficulty in making telling use of the fossil faunas in this troublesome area is, first, the undescribed nature of the fauna, and, second, the generalizations of the past. Too broad specific identifications, which sometimes included several distinct species and almost always several subspecies and mutants, and insufficient knowledge of the range of the forms and their facies relationships have created a condition in which paleontologic evidence has seemed untrustworthy, or at least, not pertinent.

[29] G. H. Girty, Geologic age of the Bedford shale of Ohio. N. Y. Acad. of Sci., Ann., vol. 22, pp. 295-319, 1903.

[30] See. C. A. Hartnagle, Classification of the geologic formations of the State of New York. N. Y. State Mus., Handbook 19, 1912. and Winifred Goldring, Handbook of Paleontology for beginners and amateurs, Part 2: The Formations. N. Y. State Mus., Handbook 10, 1931.

[31] Charles Butts, Pre-Pennsylvania stratigraphy of southwestern Pennsylvania. Penna. Topo. and Geologic Survey Comm., Report 1906-1908, p. 191, 1908.

CRAWFORD SERIES

The Crawford series (or "sub-series") includes the highest Mississippian strata in the northwestern corner of Pennsylvania and northeastern Ohio. The strata from the top of the Shenango shale to the top of the Berea sandstone constitute a genetic series such as merits a series designation. They are a faunal and depositional entity. The name "Crawford shale" has fallen into desuetude with the passage of time since J. F. Carll[33] proposed the term to include the sequence from the base of the Riceville shale through the Shenango sandstone and the red "Mauch Chunk" shale above the Shenango. White delimited the Crawford shale formation in the following year in his report on the geology of Crawford County[34]. By the new definition the Crawford shale formation included all of the strata between the Berea and Shenango sandstones, exclusive of both. The feeling has been that this formation included too much and as a result the sequence has more commonly been known as the "Meadville group", the "Sharpsville group" and the "Shenango formation".

White and Carll were perhaps more astute observers than this neglect of their classification would seem to imply. The supra-

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[32] Tentative correlation of the named geologic units of Pennsylvania, Grace Wilmarth. United States Geological Survey, 1928. **Idem**, New York, Jan. 1, 1928. **Idem**, Ohio, July 1, 1930.

[33] J. F. Carll, The geology of the oil regions of Warren, Venango, Clarion, and Butler Counties, including surveys of the Garland and Panama conglomerates in Warren and Crawford, and in Chautauqua County, New York. Second Penna. Geol. Surv., Rep. III, p. 159, 1880.

[34] I. C. White, The geology of Erie and Crawford Counties. **Idem**, Report Q4, p. 68, 1881.

Berea strata in northwestern Pennsylvania through the Shenango shale are a very closely related sequence. No marked unconformities occur in the section; in fact gradational contacts are virtually universal. These shales and sandstones are also a faunal entity which merits some classificatory expression of that relationship. Wherefore it has seemed advisable to resurrect the available and entirely satisfactory term "Crawford" for this sequence of serial or sub-serial rank.

OIL LAKE SERIES

The name Oil Lake series is proposed for the oldest major division of the Mississippian system. This is typically developed in the area covered by this revisionary study. The Oil Lake series embraces the Berea and Bedford (Cussewago of this report) portions of the Chattanoogan series of Ulrich and Schuchert. The Chattanoogan series may best show relationship in the Tennessee area, but for northeastern Ohio and northwestern Pennsylvania it is not a natural grouping of the strata. It seems to be approximately synonymous with the Crawford sub-series of this report when delimited as here proposed by the segregation of the Berea and the Cussewago into a distinct series. The Sunbury shales seems to be closely related to the Meadville formations (Meadville stage) and conceivably the Shenango stage may also be included in the Chattanoogan. However, there seems to be no good reason for including the Chattanoogan series in the present classification, because there are ample prior terms which more satisfactorily show relationship here than the use of the term Chattanoogan. The relationship of the Chattanoogan series to the strata of this area is largely hypothetical.

The name "Oil Lake" as used by J. P. Lesley[35] almost exactly covers the basal Mississippian beds herein included in the Oil Lake series. This name is highly appropriate for the series. The use of the term by Lesley was an abbreviation of I. C. White's more cumbersome "Oil Creek Lake group"[36]. In White's original group* the Riceville formation was entirely included within the Oil Lake group. However, it develops that the Riceville formation is a dual sequence, the lower part of which is of Devonian age and the upper part of basal Mississippian age. The Riceville shale proper is here included in the Devonian. The Mississippian portion is called the Kushequa shale and included at the base of the Oil Lake series**.

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[35] J. P. Lesley, editorial notes in Second Penna. Geol. Surv., Report Q4. pp. 1x and 67, 1881.

[36] I. C. White, The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, p. 67, 1881.

The Berea stage.—The Berea stage is recognized as the uppermost division of the Oil Lake series. The stage name is given for the highly characteristic Berea sandstone of Ohio. The relationship of the Berea of Ohio to the Mississippian strata in Pennsylvania has been an unsettled problem among stratigraphers for over half a century. In Ohio the Berea sandstone is a tripartite formation, composed of two sandstones with a shale between. The upper and lower sandstones of the Berea are not of identical constitution. The basal sandstone shows a marked tendency to become coarser toward the east, whereas the upper sandstone remains consistently fine, even textured in virtually its whole extent in northeastern Ohio. The fauna of the Berea (*s. s.*) is a small one, but the indications are that the lower sandstone fauna is not identical with the upper.

Whereas a great deal is known of the Ohio Berea and its southward extension, very little satisfactory information exists of the eastern correlates of the Berea, especially in western Pennsylvania. The difficulty lies in the apparent impossibility of tracing continuous outcrops of the Berea across the broad

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*The names ''Oil Creek Lake group'' and ''Oil Lake group'' were antedated by J. F. Carll's term ''Barren oil measures of the Venango'' and ''Mountain sand group'' (Report of Progress in the Venango oil district. Second Penna. Geol. Surv., Report I. pp. 1-49, 1875). For the grouping of Carll, White proposed a new name which would be less subject to confusion with the lower ''Venango oil group''.

**I. C. White was inconsistent in his classification of the Riceville shale. In the original description of the Oil Lake group (footnote 17a) he gave a thickness as 162 feet. This thickness included the Riceville shale as a glance at page 66 of his report will show. On the colored sections accompanying the report he colored the Riceville in the ''Sub-Carboniferous'' color (Sheet I, of the same report). However, in the same report White discusses the Riceville in a separate chapter between his discussion of the Oil Lake group and the Venango oil group. In this chapter the Chemung characteristics of the Riceville are emphasized, thus implying its Devonian age. On page 70 of the report White seems to include the Riceville in the Venango, while on page 71, again, he lumps it with the Cussewago. Apparently White had a feeling for the dual nature of the member which the fossil faunas clearly show today.

Grand River valley in eastern Ohio. There is no real consensus of correlation though most students of the problem have been of the impression that the Corry sandstone of western Pennsylvania is the correlate of the upper Berea, and the Cussewago sandstone the correlate of the lower Berea, and the Cussewago shale the same as the Berea shale between them.

Some of the earlier students were less opinionated than their successors. I. C. White[37], for example, was extremely ambiguous, yet inclined to consider the Corry sandstone and the Cussewago group as the Pennsylvania equivalents of the Berea. H. P. Cushing[38] in subsequent studies believed that the Corry alone was the Berea correlate. J. J. Stevenson[39] and later C. S. Prosser[40] correlated the Cussewago and the Corry with the Berea, (. . . "upper part of the Oil Lake group" . . . Stevenson). E. Orton[41] adhered to the correlation of the Corry with the Berea. G. H. Girty[42],[43] made as careful a study of the problem as anyone to date and concluded that the Corry sandstone, Cussewago shale and Cussewago sandstone were all to be correlated with the Berea.

More recent workers have grown somewhat sceptical of the accepted correlation of the Corry and the upper Berea, and still more so of the Cussewago equivalence to any part of the Berea. The ground for this scepticism is the apparent bulge which appears in a plotted section of available measured exposures of the Berea outcrops across Ohio when the diagram is continued into the Corry and Cussewago sequence in Pennsylvania. The Berea appears to grow thinner toward the east, and the inclusion of the Corry and the Cussewago apparently causes a sudden swelling in thickness. Such bulges are grounds for suspicion. G. H. Chadwick makes emphatic mention of this fact in his manuscript (1931) report on the Oil Region of Pennsylvania and in personal correspondence (1932-1933).

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[37] See, footnote 34, and Second Penna. Geol. Surv., Report Q4, pp. 209, 93, 94, 91, 85, 86, 1881.

[38] H. P. Cushing, Notes on the Berea grit in northeastern Ohio. Amer. Assoc. Adv. Sci., Proc., vol. 36, p. 215, 1888.

[39] J. J. Stevenson, Lower Carboniferous in the Appalachian basin. Geol. Soc. Amer., Bull., vol. 14, p. 41, 1903.

[40] C. S. Prosser, The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., Bull. 15, p. 395, 1912.

[41] Edward Orton, The geologic scale and geologic structure of Ohio. Ohio Geol. Surv., Report 7, p. 33, 1893.

[42] See footnote 22, above.

[43] G. H. Girty, The relations of some Carboniferous faunas. Washington Acad. Sci., Proc., vol. 7, p. 6, 1905.

As for the equivalence of the Corry sandstone and some part of the Berea sandstone, the stratigraphic position of the respective sandstones in Ohio and Pennsylvania is substantial proof. The detailed sections of Prosser's voluminous report establish that fact. Furthermore, the Corry sandstone fauna occurs in the upper Berea in Ohio. This is shown particularly well at Stratton Creek, Kinsman Township, Ohio, in the section below.

Stratton Creek Section[44]

	Thickness
5. *Orangeville shale.* Blackish fissile shale. Exposed above dam on Stratton Creek, about 2 miles above Kinsman, Ohio.	8+
4. Light gray sandstone interbedded with black shale, evidently a relic of a former thickness of strata.	.75
3. Blackish fissile shale, weathering brownish.	4.5
2. *Berea sandstone.* Light colored, gray to buff sandstone which weather to a rusty brown tone due to disintegration of marcasite nodules in the upper portion. Rather massive layers of which are cross-bedded. Fossiliferous. Chief fossils are inarticulate brachiopods, Lingulae, Discinae and very large Oehlertellae. Fragments of Syringothris and Paraphorhynchus as well as clams and Platycerata also found. Marked similarity to Corry fauna. Fossils most abundant in the upper portion, though occurring throughout the exposure below the old dam. Some local quarrying in the upper beds.	4.5
1. Thin-bedded, bluish sandstone of fine quartz grains. Layers varying in thickness. Exposed intermittently from the foot of the falls under the dam to below the bridge over Stratton Creek near the Hamilton mill. In about the middle of the section is a fossil zone in which were found brachiopods and clams, and an especially fine ‘ milliped’’.	25+
A. Unknown subsurface interval, about	40+—
B. Sandstone, in a water well, coarse, presumably the *Cussewago,* about	15+—
Total	97.75 ft.

In several localities fragments of marine fossils in the upper Berea have been found. The fauna is essentially that of the Corry sandstone. Lithically the upper Berea and the Corry are indistinguishable.

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[44] Compare with Prosser's section on Stratton Creek. (Ohio Geol. Surv., Bull. 15, p. 369, 1912.)

At Williamsfield, Ohio, and in ravines thereabout several exposures of the Berea in its Corry phase, can be seen. This is another occurrence on the eastern side of the Grand Valley lacuna. In a stream bed, one-half mile north of Williamsfield Post Office, Ohio, the following section occurs.

Section One-Half Mile North of Williamsfield P. O.[45]

		Thickness
9.	*Orangeville shale.* Alternate layers of black shale and sandy shale and sandstone. Some layers carrying a Lingula fauna.	12
8.	*Berea sandstone.* “Top of sandstone occurs in the bed of the stream, not far below the railroad fill, and it contains numerous pits, caused by the weathering out of nodules of marcasite and iron pyrites. These upper sandstones are bluish-gray to buff in color, weathering brownish, composed of rather fine grains of quartz sand; are thin-bedded and split up rather unevenly. They are only 2 or 3 feet in thickness and correspond to the Corry sandstone of Dr. I. C. White in western Pennsylvania. Below are much thinner bedded sandstones to shaly sandstones and shales. The thin sandstones in this zone are much ripple-marked. There is an occasional layer of bluish gray, fine-grained, quartz sandstone 6 or so inches in thickness. These layers weather to a brownish color and are not so very different in lithologic appearance from those of the Berea formation as shown in the Lithopolis Glen, southeast of Columbus, in Central Ohio”.	10
7.	“Zone of several layers of sandstone from 4 to 6 inches thick, which split into 1- to 2-inch layers. It is bluish gray, weathering to a brownish gray, and coarser grained, quartz sandstone than those above, containing some clay pebbles. A little higher than the base are some small and old quarries . . . ”	4
6.	“Shaly sandstone to shales, which are blue in color, and shown on the stream bank a short distance above the State road. Some of the shale is argillaceous; but part of it is arenaceous, containing grains of white quartz sand. Some of the thin, irregularly-bedded sandstones are ripple-marked. The rocks of this zone more closely resemble lithologically the Bedford than those of most of the section.”	3.5
5.	Covered interval, above and below the highway	15
4.	“Thin-bedded micaceous sandstones, which are greatly ripple-marked, and composed largely of grains of rather fine quartz sand. In some of the layers the quartz grains are rather coarse, especially in the lower part of the zone. They contain considerable marcasite, and certain layers are decidedly blue in color, although part are buff. There is a great number of ripple-marked layers, and the ripples run in different directions on different layers”	12
3.	Covered zone	10
2.	Thin-bedded, coarse-bedded quartz sandstone	1
1.	“Top of massive Cussewago sandstone, as shown in bed of run. A massive, buff, quartzose sandstone, which is very friable, with lithologic appearance of the Cussewago sandstone of western Pennsylvania. When wet in the bed of the stream the sandstone	

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[45] C. S. Prosser, **Idem**, p. 374.

is much more friable than when dried out on the higher bank of the run. There are harder beds which are thinner, alternating with the soft ones, and it also contains some ironstone pebbles. When wet the color is rather greenish-buff, but light buff when dry. The lowest outcrop occurs in the bed of the run . . .'', exposed	21
Total	88.5 ft.

This section is important for showing the best exposure known to date of the Corry and Cussewago in the same section. Here, as elsewhere, there is good evidence for a break in the midst of the eastern Ohio Berea sandstone formation at the top of the Cussewago shale (Hayfield shale, numbers 2, 3, 4, 5 of the above section). The Corry sandstone is of remarkable lithic similarity to the Berea sandstone in this section.

Unless much more evidence is found, than is available at present, it would be advisable to withhold opinion on the Ohio equivalent of the Cussewago shale and sandstone of western Pennsylvania. No brief is here held for the equivalence or the coevality of the Cussewago shale and sandstone with the lower Berea sandstone of Ohio, although their relative positions immediately suggest correlation. So far as known, there is no marked similarity between the upper and the lower Berea sandstones. They are faunally distinct in eastern Ohio, though definitely belonging in the same series on the basis of broader faunal relationship. The Corry sandstone belongs in the same *series* as the Cussewago beds below. The upper and the lower Berea are of different texture in central Ohio, as is well shown in Lithopolis Glen, near Columbus, and elsewhere throughout the central area. Prosser remarks on the similar appearance of the tougher beds of the Cussewago in eastern Ohio with the lower Berea of central Ohio, thus suggesting their correlation, in which he believed.

There are then several possibilities of correlation, none of which materially modify the stratigraphic classification as here outlined. The upper Berea and the Corry sandstone are one and the same deposit. The lower Berea of central Ohio may or may not be the correlate of the Cussewago stage of eastern Ohio and western Pennsylvania. The suggestion deduced from field evidence of deep scour in places through central Ohio at the base of the Berea is that the Berea may have been deposited with a summit disconformity over the Bedford, the upper strata of the latter being represented by the Cussewago beds. Certainly the Cussewago beds are the closing stage of a depositional era in Pennsylvania which was contemporaneous with the Bedford depositional era in Ohio. This seems to be definitely established. The Berea stage of eastern Ohio and Pennsylvania is represented by the Corry sandstone only. The lower Berea of central Ohio may belong in the same stratigraphic stage. Certainly the Cussewago sequence of eastern Ohio and western Pennsylvania does not.

It would seem that the Berea is made up of strata of two quite distinct time divisions. The lower Berea seems to be identical with the Cussewago sandstone (and shale?) the lithology of which is very characteristic. The upper Berea is of marked lithic dissimilarity to the lower in eastern Ohio, and of a different faunal stamp as well. These two are separated in places by a shale interval in the middle Berea.

G. H. Chadwick is somewhat sceptical[46] of the old idea of Berea, Corry, Cussewago correlation. Indeed, this scepticism seems justified if one plots all the available sections from the vicinity of Cleveland, Ohio, to Meadville, Pennsylvania, in which the Berea and Corry occur. There develops a large "bulge" in the formation at the point where the Cussewago comes in. This would suggest as it has to Chadwick, that perhaps the Cussewago strata come below the Berea proper, and that summit disconformity perhaps explains the apparent continuity. This is unproved.

The "Berea stage" is as present designed to account for the Corry sandstone at the top of the Oil Lake series. There is reasonable certainty that this formation is the eastward continuation of the upper Berea sandstone of Ohio. The Corry belongs in the Oil Lake series faunally, and lithically, rather than in the Crawford series. It cannot justifiably be included in the Cussewago stage. Wherefore a separate stage is created for it.

The Cussewago Stage.—The Cussewago stage includes all of the Oil Lake strata below the Corry sandstone in western Pennsylvania. The name Cussewago first appeared in stratigraphic literature in I. C. White's report on Crawford and Erie Counties of Pennsylvania (Q4, pp. xvi and 66, 1881). Under this head were described three independent "formations", the Cussewago limestone, Cussewago shale and Cussewago sandstone. In the measured section (*Idem*, p. 70) of White's report these three are bracketed together, thereby implying, it would seem, that these three units are "members" of a common formation. The definition (*Idem*, pp. 94-95) treats these three as distinct units as does also the Table of Contents. No formal description of the "Cussewago formation" is given by White. On the basis of the somewhat indefinite designation of classificatory niche in which the Cussewago strata are to be construed as belonging, Chadwick[47] (1925) proposed to give separate formational names to the shale and limestones (Hayfield shale and limestone) and limited the name Cussewago to the sandstone which he considered to be the most characteristic member of the triad.

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[46] Personal correspondence and Manuscript report on the oil sands of Pennsylvania (1931), 1932-33.

The present attitude is that White's designation was that of a "formation", despite the absence of formal description as such. His discussion of the individual members is ample, and no separate collective description was necessary. Furthermore, when studied in the field it is proved beyond question that the Cussegawo shale and limestone (Hayfield (Chadwick) and Littles Corner (Caster) and Cussewago sandstone are a gradational, genetic series. White was presumably familiar with this natural relationship and out of utter familiarity neglected to point it out. The classification must include the three members in one category, call it what one will. White termed the three members all Cussewago. Presumably the original usage is still best. Wherefore, the suggestion is made that White's triad of formations be recognized as the Cussewago "stage" of which the Hayfield shale, Littles Corner limestone and Knapp formational suite ("Cussewago sandstone" and Knapp conglomerates) and the genetically related, underlying Kushequa shale are the component parts. (See Catalogue of Strata, below, for detailed discussion). This nomenclature is acceptable by priority of usage, and best shows relationship, which after all is the sole purpose of scientific, systematic nomenclature.

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[47] G. H. Chadwick, The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, pp. 455-464, 1925.

DEVONIAN SYSTEM

The Upper Devonian is at present divided into the Senecan and Chautauquan series. The Senecan series includes the strata above the Hamilton group to the base of the Chemung formation of New York. This is a sequence meriting serial rank, but the upper boundry will have to be redefined in the near future. The present interest centers above the overlying Chautauquan series. The Chautauquan series embraces the strata from the base of the Chemung to the base of the Bradfordian series of former classifications. The Chautauquan series was viewed by the New York State geologists as marking the close of the Devonian. The overlying Bradfordian was considered of Mississippian age.

The Bradfordian series must go, as has been previously explained under the discussion of Mississippian classification. For the Devonian portion of the Bradfordian "series" the name Conewango series is appropriate. The original "Conewango formation" of Butts[48] precisely covers the Devonian portion of the former Bradfordian system, and now on the demise of the latter, should be elevated to series rank.

The original Conewango series[49] included the Cattaraugus formation (which is a synonym for the Venango stage) and the Oswayo formation of the Olean and Salamanca region of New York. The classification of the Upper Devonian strata of southwestern New York, and northwestern Pennsylvania is shown on the preceding outline.

THE CONEWANGO SERIES

The Conewango series is the closing phase of Upper Devonian sedimentation in New York and Pennsylvania. At its base occurs a minor disconformity, separating it from the inferior Chautauquan series. At its top a minor disconformity occurs which is the break between the Mississippian and the Devonian systems. The actual lithologic breaks at the top and bottom of the series are relatively inconsequential disconformities. The outstanding criterion for serial delimitation of the Conewango is the fossil fauna or faunas. They are highly distinctive. The

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[48] See, footnote 31. **Idem, p. 191.**

[49] See, footnote 26.

Conewango fauna assemblage is in the main derived by mutation from the Chautauquan faunas below. Notable new additions to the mutational fauna however, do occur at the base of the Conewango; among these are the pelecypods *Pararca* and *Ptychopteria.* The faunal change at the top of the Conewango is of much the same sort that marked its inception. The Conewango fauna crosses the Devonian-Mississippian disconformity in mutated form, but on the near side of the break many Mississippian genera appear in an abrupt array of specialized forms. Such genera as *Syringothyris* and *Rhynchospirina,* as well as several characteristic genera of echinoids are among these new-comers of definite Mississippian stamp.

There is an almost uninterrupted sequence from the Uppermost Devonian into the basal Mississippian, only a lost time record of minor importance separates the two systems, yet it seems probable that this minor hiatus is a local expression of a far greater hiatus elsewhere. Apparently new sea connections developed about this time somewhere else, marking the beginning of Mississippian sedimentation in eastern America. However, so peacefully was the new period begun that the Upper Devonian seas experienced barely more that a gigantic ripple, a sudden withdrawal followed by a speedy return of the sea to approximately the same confines. The returned waters were populated in the main by Devonian mutatants, but in addition there were certain new forms which did not occur in the Devonian seas of eastern America, forms which were to become the predominant marine biota of the later Mississippian.

The fact that the new-comers to the "Bradfordian" area are not especially primitive members of their respective lines, but when they first appear are full-fledged Mississippian organisms, indicates that presumably in chronology the Upper Devonian of New York and Pennsylvania was deposited coevally with the older Mississippian of some parts of the world. This deferred commencement of a period in one region in relation to another is due to a seeming concentric rhythmicality of intersystemic diastrophism, particularly when the diastrophism was relatively slight. The beginning of a system is placed in any given region at the point in the stratigraphic column where the effect of the intersystemic movement is first recorded. The break at the top of the Conewango is the point in the western Pennsylvania column where the Mississippian begins. The fact that the actual intersystemic movement was locally not appreciably greater than some movements occurring in the midst of the Devonian below, is unimportant. The difference is illustrated by dropping rocks in a pool of water. The effect of the resulting ripples on a toy boat close to the point where a small pebble was dropped might be much more disastrous than on the same boat at a greater distance from the splash and ripples of a much larger rock.

The Conewango series is represented across northern Pennsylvania and Ohio by several parvafacies, a number of which have been given stratigraphic names either in part or wholly synonymous with the Conewango series which embraces all the coeval facies across the states. Some stratigraphers have spoken of the Conewango sequence as the "Cattaraugus formation", which is utterly without basis. Their feeling has been that perhaps the Oswayo beds which overlie the Cattaraugus beds in the Olean area are merely upper beds of the Cattaraugus which had been subjected to pre-Pottsvillian leeching. This is not the case. A disconformity separates the Oswayo from the Cattaraugus as was stated in the original discussion[49]. The sections recorded below illustrate one occurrence of this disconformity. It so happens, however, that the beds which were called Cattaraugus are an eastern coevality of the Venango beds which were previously described from western Pennsylvania. The name Cattaraugus must either pass into stratigraphic synonomy or be retained in a very useful capacity as a *facies* term. It is unfortunate that the original application[50] of the term Conewango to a field occurrence was highly ambiguous and misleading. By the original definition[48] there was no such ambiguity, and in this sense the term is extremely useful.

The Conewango series is represented from west to east by the following parvafacies; black shale parvafacies (?) of the Cleveland magnafacies; shale and sandstone parvafacies of the Chagrin magnafacies; coarser sandstones and conglomerates with interbedded fine shale, a parvafacies of the Irvineton magnafacies; Cattaraugus parvafacies of an unnamed magnafacies which is characterized by purple shales and conglomerates; coarser sands and shales; a parvafacies of the brilliantly red Catskill magnafacies etc.

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[50] Charles Butts, Description of the Warren quadrangle, Pennsylvania-New York. U. S. Geol. Surv., Geol. Atlas, Warren folio, (no. 172,) 1910.

The Conewango series is represented in Potter and eastern McKean Counties of Pennsylvania by coarse, micaceous sandstones and flaggy shales, the so-called Oswayo of those regions, and so far as known does not occur much beyond Bradford County. It is probably cut out of the section beyond that area. The so-called Cattaraugus red beds of Tioga County, Pennsylvania, and of Barclay Mountain, Bradford County, are not the stratigraphic equivalent of the type Cattaraugus. They are, according to correspondence with G. H. Chadwick[51], of Chadakoin and Girard age. Only the so-called Pocono of Barclay Mountain is the stratigraphic equivalent of the Cattaraugus, and the Conewango.

The Conewango series is replaced by red beds to the *south and south east* of the "Bradfordian" area. Whereas it is the lower portion of the Conewango series which is so rapidly replaced to the east by red beds, it is the Oswayo, or upper portion of the Conewango which is replaced with great rapidity toward what might be thought of as an Appalachian delta somewhere to the southeast of Altoona. This is suggestive of a possible shifting of the center of deltaic deposition in closing Devonian times from the Catskill area in the east, toward the southeast across the area which Schuchert[52] terms the "New Jersey straits" of early upper Devonian. These facts of southeastward assumption of red beds in uppermost Devonian time are rather clearly shown in the large series of well-sections published in the various county reports of the Second Pennsylvania Survey.

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[52] See footnote 19. **Idem,** p. 550, 1910.

[51] Letter of March 24, 1933.

The Conewango series is subdivided into the Riceville and the Venango stages. The Riceville stage as here recognized is only the lower part of the original Riceville of I. C. White. The discussion of this differentiation occurs under "Riceville" in the Catalogue of Strata, below. It seems from the original and subsequent descriptions of the Riceville that I. C. White was impressed with the Devonian aspects of the formation. The lower part of the original Riceville only is of Devonian age. This is the Riceville stage. There is something to be said for Chadwick's classification[47] of the Riceville as the closing member of the Venango stage. (Chadwick's usage of the term Riceville was in the original sense, of course.) However, when the Riceville is traced eastward into its Oswayo equivalent, the change from the Venango to Oswayo is lithically and faunally so great as to require some designation more emphatic of distinction than "member" implies. The Venango stage is discussed in some detail in the Catalogue of strata, below.

The Cattaraugus facies.—The Cattaraugus formation of L. C. Glenn[26] is an exact synonym of the original "Venango group" of White. The only proper use of the name "Cattaraugus" is in a facies sense. In this usage it is extremely convenient and clarifying. The Cattaraugus beds were described by Glenn from the Olean area where they overlie the upper beds of the "Chemung group" (Chadakoin) and were supposedly the western equivalent of the Catskill red beds to the east. The Cattaraugus beds are purplish red and green in color and are interstratified with locally massive conglomerate lenses of varying numbers in different localities. These conglomerates are a highly characteristic feature of the magnafacies of which the Cattaraugus sequence is a meridional, parvafacies development.

West of the Allegany State Park area of New York, the Cattaraugus beds lose their characteristic purple hue, and become normal olivaceous marine shales and sandstone. The Conglomerate bands continue either intermittently or in some instances continuously into the new facies province. It was in this marine province that the "Cattaraugus beds" were first studied and wherefrom the name Venango was first applied to the sequence.

"Cycles".—Some stratigraphers have considered the Cattaraugus or Cattaraugus and Riceville as constituting a sedimentary

cycle, emphasis being placed on the paired occurrences of conglomerates and shales through the series. As a matter of fact when closely studied the sequence from the Cuba sandstone through to the top of the "Bradfordian series" illustrates the "death throes" of a period, the record of which is initiated by the deposition of a flat-pebble, shore-formed conglomerate and sandstone. The Cuba was followed by submergence during which the Girard shale was deposited. This in turn was succeeded by elevation and deposition of the Lillibridge ("Quarry") sandstone at the base of the Chadakoin formation. The Conewango series beginning with the basal Venango conglomerate, the Wolf Creek, is merely a continuation of this record of a thready pulse. In this expiring stage certain new (new to the area, at least) faunal elements appear. This appearance might be attributed to changing currents resultant to elevation or submergence of controlling influences, or simply to the sinking of previously existing barriers in remoter parts of the epicontinental sea by which the territory under observation was submerged by a narrow embayment. As the end of the period drew near the ups and downs succeeded each other in more rapid succession. The alternation of shore with near-shore sediments became characteristic. In its typical development the Conewango series represents the shallow, near-shore zone of deposition where minor oscillations cause or tend to cause major sedimentary disturbances; the zone of scour and fill; disconformity. As a whole the Conewango marks the close of a great cycle of deposition; a cycle initiated by the deposition of the shore sand of the Oriskanian sea in the Lower Devonian. It might more nearly express the case were it said that the "Bradfordian" marks such a close of a sedimentary cycle, for the lowest Mississippian strata in the western Pennsylvania embayment (the Knapp shales and conglomerates) were deposited in an Upper Devonian physical setting.

The basal conglomerate of the Conewango (Panama-LeBoeuf-Wolf Creek) as well as the medial conglomerate (Salamanca suite) and the upper stratigraphically less important conglomerates (Woodcock, Hosmer Run, Tunangwant, or Kilbuck) are simply the more continuous, or more extensive conglomerates in this closing sequence. They are by no means the entire roll of conglomerates occurring in the Upper Devonian of western Pennsylvania. It is the profusion of local conglomerates in the midst of virtually all of the shale members between the major conglomerate horizons that makes the field work in northwestern Pennsylvania at times most perplexing. It is not an infrequent experience to find a very much localized conglomerate lens of far greater development than the more persistant and hence more important conglomerate members. Nor is it a rare occurrence to find the major conglomerate practically eliminated from a section by subsequent local scour.

THE CHAUTAUQUAN SERIES

The original scope of this revisionary study did not include the Chautauquan series, but as an incident in the examination of the lowest Conewango strata in southwestern New York and northern Pennsylvania many Chautauquan sections have been studied. The results of this, especially of the uppermost Chautauquan beds seem to merit inclusion here.

The Chautauquan series was proposed for the Uppermost Devonian strata in New York, beginning at the base of the Chemung and ending at the base of the Carboniferous. The series is a convenient mnemonic grouping, and at the same time justified as a series on the basis of its distinct faunas. The Chautauquan series is comparable to the overlying Conewango in its facies constitution. All of the magnafacies transected by the Conewango are cut across by the Chautauquan series as well. The initiatory fauna of the Chautauquan series is derived from more easterly and stratigraphically lower parvafacies expressions in the Senecan series. As at the beginning of the Conewango series, so also at the beginning of the Chautauquan the real basis of separation into a stratigraphic series is the appearance of certain new faunal elements not autochthonous to the magnafacies in their earlier expression. Probably if enough was known of the Upper Devonian seas in their planar extent no series differentation would be necessary. From the facts available ,such a segregation is convenient and helpful.

The diagrams above illustrate the intimate relationship which exists between the series of the Upper Devonian. The horizontal lines on that diagram correspond to the boundaries of the series and the diagonal lines represent the magnafacies planes. So closely do the facies faunas correspond in diagrammatic scheme to the lithic facies that these figures serve almost equally well for either. It is obvious that if fossil faunas do follow some general plan they may be most useful stratigraphically. Their usage however cannot be casual. Close study, and assiduous observation are required to make the best use of the fossil faunas. It is not an uncommon condition that there is greater horizontal (contemporaneous) than vertical (diagonal, facies) variation within species groups (gens). Unless this fundamental condition is recognized the faunas will ever be as useless for extensive correlation in the great "Chemung complex" as they have been heretofore.

The Chautauquan series includes at its top a group of strata which have been termed by Chadwick the "Chadakoin beds" in western New York. These beds are divisible into several members of faunal and lithologic dissimilarity. Although the entire Chautauquan series is in pressing need of revisionary study, only the Chadakoin portion has been incidentally included in this survey. The present examination of the Chadakoin is incomplete. No careful analysis of the parvafacies elements developed in the several members has been made.

CATALOGUE OF STRATA[53]

The Devonian and Mississippian strata in northwestern Pennsylvania and the adjacent part of New York State form the basic substance matter of this report. This catalogue is designed briefly to describe the respective members of these systems exposed at the surface within the specified area. Members will be considered in ascending sequence.

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[53] If the terminology of this paper is compared with that used in a preliminary abstract of the same problem by the writer in December 1932 (Geol. Soc. Amer., Bull., vol. 44, pp. 202-203, 1933 abstract) certain discrepancies will be apparent. The new names used in the abstracted account proved in several instances to be preoccupied in stratigraphic literature. For the preoccupied names, acceptable names as follows are used:

For Glade sandstone of the abstract, Cobham sandstone is used.
For Ridgway shale of the abstract, East Kane shale is used.
For Ludlow conglomerate of the abstract, Wetmore conglomerate is used.
For Smethport shale of the abstract, Kushequa shale is used.
For Wild Cat coquinite of the abstract, Roystone coquinite is used.

PALEOZOIC GROUP

DEVONIAN SYSTEM

Chautauquan series

CHADAKOIN STAGE

The rocks of the Chadakoin stage were first segregated from the upper Chemung group of older writers by G. H. Chadwick[54] in 1924. For the "highly fossiliferous Chemung beds" which outcrop extensively in Erie County, Pennsylvania and are characterized by "*Leiorhynchus newberryi* fauna," the designation as "Chadakoin beds" was made. The typical exposure of the Chadakoin beds is along the Chadakoin River in brick shale quarries at Dexterville (East Jamestown), New York. It is interesting to note that at the type occurrence the *Leiorhynchus* fauna is absent. This fauna which is eminently characteristic for the western facies of the Chadakoin (Chagrin facies province) does not extend eastward into the type area.

The base of the Chadakoin formation (or "beds") was taken as the "quarry sandstone" of the Olean region. The top was at the contact with the overlying Cattaraugus (Conewango). The Chadakoin was therefore defined as extending from the base of the Quarry sandstone to the base of the Panama conglomerate (Wolf Creek conglomerate), basal member of the Venango stage. Although wholly inadequate stratigraphic work has as yet been done on the Chadakoin sequence it appears advisable to delimit certain members within the terrane. The Chadakoin beds have been studied somewhat casually about the city of Jamestown, along Chautauqua Lake, in the vicinity of Olean and Salamanca and southward in the adjoining part of Pennsylvania. From this cursory study it appears that Chadwick's "beds" have the dimensions of a stage and monothem in accordance with the scheme of stratigraphic classification previously outlined in this report.

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[54] The stratigraphy of the Chemung in western New York, N. Y. State Mus., Bull. 251, p. 154, 1924.

STRATIGRAPHIC MEMBERS OCCURRING IN NORTHWESTERN PENNSYLVANIA

		PARTIAL SYNONYMY	
MISSISSIPPIAN SYSTEM			
Waverlyan subsystem			
Kinderhookian series			
(Crawford sub-series)			
Shenango stage			
(Shenango monothem)			
Hempfield shale member*		*Shenango shale*	
Shenango sandstone member (Johnsonburg sandstone*)		*"Sub-Olean conglomerate"; 2nd Mountain sand.*	
Meadville stage			
(Meadville monothem)			
Custards shale member*		*Upper Meadville shale*	*Original Meadville group*
Conneaut limestone member*		*Upper Meadville limestone*	
Harvest Home shale member*		*Lower Meadville shale*	
(Byham limestone member*)		*Middle Meadville limestone*	
Sharpsville sandstone member	Sharpsville formational suite	*"Sub-Olean conglomerate"*	*Original Sharpsville formation*
West Mead limestone member*		*Lower Meadville limestone*	
Shaws sandstone member*		*Sharpsville sandstone*	
Orangeville shale member (stage?)		*"Cuyahoga" of Pennsylvania*	
Oil Lake series			
Berea stage			
Corry sandstone member		*3rd Mountain sand; Pit Hole Grit*	
Cussewago stage			
(Cussewago monothem)			
Hayfield shale "formation"		*Cussewago shale*	
(Little's Corner limestone member*)		*Cussewago limestone, Hayfield limestone*	
Tidioute shale member*			
Cobham conglomerate member*	Knapp formational suite	*Upper Knapp conglomerate; Cussewago sandstone*	
East Kane shale member*		*Knapp shale (middle)*	
Wetmore conglomerate member*		*Lower Knapp conglomerate*	
Kushequa shale member*		*Knapp shale*	
(Marvin Creek limestone zone)		*Marvin Creek limestone ("Meadville limestone")*	
DEVONIAN SYSTEM			
Conewango series			
Riceville stage			
(Riceville monothem)			
Oswayo shale member		*"Red Bedford" of the Oil Region*	
Roystone coquinite member*		*Mistaken for the Marvin Creek limestone by some geologists*	
Venango stage			
(Venango monothem)			
Woodcock sandstone member		*First Venango oil sand*	
(Hosmer Run conglomerate)			
(Tuna-Kilbuck conglomerate lens)			
Saegerstown shale member			
Pope Hollow conglomerate	Salamanca formational suite	*"A"*	
North Warren shale member*		*Second Venango oil sand*	
Bimber Run conglomerate member*		*"B"*	
Amity shale			
(Dutchman's conglomerate lens*)			
Panama conglomerate member		*Third Venango oil sand*	
Chautauquan series			
Chadakoin stage		*"Upper Chemung"*	
(Chadakoin monothem)			
(Tanners Hill red band)			
Ellicott shale member*		*"Pink Rock"*	
Dexterville shale member*			
Lillibridge sandstone member*		*Quarry sandstone*	
Girard stage			
Girard shale			
Cuba sandstone			

***Note:** Members marked with an asterisk (*) are designated by geographic name for the first time in this report.

LVANIA

Mississippian Sys
Waverlyan subs
Kinderhookian
(Crawford sul
Shenango st
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Hempfield
Shenango
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harpsville formation
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Cussewago st
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Ellicott sha
Dexterville
Lillibridge
Girard stage
Girard shale
Cuba sandst

***Note:** Members ma
rt.

The Chadakoin beds lie wholly above the Chemung section on the Chemung River between Big Flats and Elmira, New York. On the Elmira meridian the Chadakoin strata are represented by "Catskill" beds. From the general area of Corning, New York westward the red color gradually gives way to pink and in the western part of the state to normal olivaceous. In the Oil Region of Pennsylvania and northward on the outcrop in New York the Chadakoin beds are spoken of as "pink rocks." This is to differentiate the Chadakoin from the overlying purple and chocolate rocks of the Venango stage which overlie them in this area.

Lillibridge sandstone member.—The basal member of the Chadakoin stage has heretofore been known as the "Quarry sandstone" from the occurrence in stone quarries (now abandoned) in and about Olean, New York. Quarries in this member were formerly very numerous about the foot of Mount Herman, at Olean. This member is being renamed Lillibridge sandstone from Lillibridge Creek which flows southward to the Allegany River one mile northeast of Portville, New York. Outcrops occur naturally along Lillibridge Creek, and in quarries adjacent to it. The Lillibridge sandstone is predominantly flaggy with intercalated shales. It is usually pinkish to purple red in color and not abundantly fossiliferous in most exposures.

The fauna of the Lillibridge sandstone on the Olean meridian was listed by Charles Butts[55] in his report on the fossil faunas of the Olean Quadrangle. Butts's list is incomplete, but even from it the facies relationship of the fauna can be deduced. The Lillibridge fauna of the Olean area is a parvafacies faunal expression of the Big Bend magnafacies. The Big Bend facies nature prevails into the Jamestown area but the "Chagrin" facies elements begin to appear a little west of Jamestown and the assumption is complete on Lake Erie. The "Chagrin" facies expression continues on into Ohio as the Chagrin element of the member.

Dexterville shale member.—Above the Lillibridge or "Quarry sandstone" member is what may be thought of as the typical Chadakoin, inasmuch as it is the member best shown in the greater part of the Dexterville quarry exposure of the Chadakoin. This member takes its name from the brick quarries, south of the Chadakoin River in East Jamestown, formerly known as Dexterville. Only the upper part of the member is shown at Dexterville, where it is a blue shale and flag series carrying the Chadakoin phase of the "C" facies fauna, which is characterized in the area about Jamestown by the abundance of brachiopods of many sorts, of which *Camarotoechia duplicata* is particularly numerous. Eastward in the Allegheny State Park and about Olean, New York, this member assumes the chocolate phase of magnafacies "B". The chocolate Dexterville parvafacies contains an extremely abundant fauna which has been recorded by Butts in his *Zone* 10 (see reference under Lillibridge). The following section in the quarry at Dexterville will demonstrate the nature of this member.

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[55] See footnote 27.

Section north side and at the foot of "Swede Hill," Dexterville brick shale quarries, East Jamestown, New York.

		Thickness
17.	*Ellicott shale monothem.*—Junction of Willard street and Pardee avenue, "Swede Hill" Jamestown, New York; el. 1460 A. T.; green platy shale and sandstone with fossiliferous lenses which weather to chocolate color. *Spirifer disjunctus, Camarotoechia contracta* and *Leptodesma potens* abundant. This is near the base of the Ellicott shale member.	42. ft.
16.	Concealed interval, not dissimilar to quarry sequence if rubble evidence is to be depended on. Approx.	140. ft.
15.	*Dexterville shale monothem.* Chocolate shales and lenticular masses of greenish olive sandstones to the top of the quarry, also occasional fossil zone and localized coquinites. Bedding very undulatory.*	60. ft.
14.	Shale and sandstone, latter greenish, former chocolate. *Camarotoechia duplicata* sporadically present in abundance	15.75 ft.
13.	Chocolate shale and sandstone, fossils present.	3. ft.
12.	Green shale and sandstone. Fossils; no limy layers.	21. ft.
11.	Limy shale, green, containing large fauna of Brachiopods, chief of which are: *Camarotocchia contracta, C. duplicata, Spirifer disjunctus* and *Stropheodota* sp.	2. ft.
10.	Sandstone and shale with sparse distribution of *C. duplicata.*	10. ft.
9.	Greenish, rather fissile shale	3. ft.
8.	Massive sandstone with a 4 inch resistant sandy limestone at base.	2.50 ft.

*About 100 feet above the floor of the quarry, in No. 15 of the section is a 3 foot band of reddish shale, the first in the sequence.

7.	Greenish shale.	3. ft.
6.	Sandstone carrying fossils, same assemblage as No. 4.	2. ft.
5.	Shale and sandstone.	2. ft.
4.	Coquinite, ''firestone'' containing a brachiopod fauna in which the following are abundant: *C. contracta, Spirifer disjunctus, Athyris* cf. *angelica, Mytilarca* sp. and *Productella* sp.	.50 ft.
3.	Shale and sandstone.	5. ft.
2.	*Camarotoechia duplicata* zone, greenish shale and flags.	5. ft.
1.	Greenish shale and sandstone.	5. ft.
	Total	321.75 ft.

*Fauna of the Dexterville shale, chocolate facies, in the vicinity of Olean and Salamanca**

Spirifer disjunctus Sowerby (Mut)
Athyris angelica Hall
Athyris sp.
Camarotoechia contracta (Hall) (gens)
Camarotoechia aff. orbicularis (Hall)
Chonetes scitulus Hall
Dielasma (?) sp. nov.
Lingula sp.
Crania sp.
Orbiculoidea sp.
Schizophoria leonensis (Hall)
S. tioga (Hall)
Productella lachrymosa Hall
Aviculopecten tenuis Hall
A. duplicatus Hall (mut?)
Aviculopecten n. sp.
Crenipecten crenulatus Hall
Edmondia phillipi Hall
Leptodesma potens Hall
Leptodesma potens (mut)
L. mortoni Hall
L. sociale Hall
Mytilarca chemungensis (Conrad)
Nucula sp.
Pteronites profundus (?) Hall
Oleanella (?) sp.
Pterinopecten crenicostatus Hall
P. neptunus Hall
Schizodus aff. cuneus Hall
Sphenotus clavulus Hall
S. contractus Hall
Sphenotus 2 n. sp.
Grammysia subarcuata Hall
Grammysia sp.
Orthoceras 2 sp.
Bellerophon maera Hall
Cyclonema n. sp.
Straparollus aff. hecale Hall (n. sp.?)
Prismodictya choanea Hall and Clarke
P. prismatica Hall

*Based on a re-examination of the Butts-Glenn collection at the New York State Museum, and on personal collections. List not complete.

Prismodictya choanea Hall and Clarke
T. edwin-halli Hall and Clarke
Crinoids and Bryozoans

Ellicott shale member.—The Ellicott shale member overlies the Dexterville member and is roughly comparable in its vertical extent to "Zone 9" of Butts's analysis of the fossil faunas of the Olean area. The Ellicott shale is a well marked lithic and faunal member and merits segregation from the Dexterville.

The type occurrence of the Ellicott shale is along the "Hunt Road," between Ashville and Jamestown, New York where it is exposed in roadside cuts. This is in the town of Ellicott, Chautauqua County. Excellent exposures are found on the Stoneman farm at the junction of the Hunt and Sugar Grove roads, town of Busti, Chautauqua County. There are also fine exposures in the ravines and gullies about Ashville and Panama and along the west shore of Chautauqua Lake. The ravines on the Stoneman farm are the finest locality known for the collecting of the fauna of the Ellicott shale.

The fauna of the Ellicott is inadequately known, but is characterized in the type locality by the abundance of pelecypods and a mutational form of *"Spirifer disjunctus"*. The rather abrupt faunal change at the top of the Dexterville which is indicative of a rather sudden shift in the deltaic facies toward the west seems to be good basis for the differentiation of a new member. The fauna of the Ellicott on the Stoneman farm is apparently largely made up of mutatant descendants of the Wellsburg monothem to the east.

Near the top of the Ellicott shale, in virtually every section in which the upper beds of the member are exposed a zone of *Chonetes* cf. *lepidus* is found. This occurs from 2-4 feet below the base of the overlying, disconformable, basal Venango conglomerate. Such a zone has been observed in the shale immediately below the Wolf Creek conglomerate near Olean. The zone has been absent in only those sections in which it appears that there had been considerable scour prior to the deposition of basal Venango strata.

The Ellicott shale is best known from only portions of two facies expressions. In the Olean area the Ellicott is represented by a quite different facies expression from that at the Stoneman farm. Butts has made a partial study of the fauna of the Ellicott about Olean where he lists it as his "zone 9". This is a parvafacies expression of magnafacies "B". As traced westward the Ellicott assumes the Cattaraugus and then the Big Bend magnafacies. In Ohio the Ellicott member is represented by a part of the Chagrin "formation" ("Chagrin" magnafacies). As traced toward the west from the Jamestown district the gradual assumption of the *Leiorhynchus newberryi* ("Chagrin" facies) fauna is obvious.

In about middle Ellicott time a marked temporary westward advance of the Catskill delta occurred. This is shown by the lack of homogeneity from top to bottom of almost every section of the Ellicott. In the Jamestown area middle Ellicott time is marked by the appearance of reddish beds above a more seaward olivaceous shale facies expression, of the lower part of the member. Upper Ellicott shale was deposited under conditions quite similar to those under which lower Ellicott was deposited, at least in New York State.

In the Warren, Pennsylvania region near the top of the Ellicott there is a bright red paint rock layer, the so-called "Tanners Hill red" band much mentioned in Pennsylvania reports[56]. A red layer, two or three feet thick occurs beneath the Panama conglomerate in the Wrightsville and Lottsville region, just west of Warren, Pa. This is presumably the Tanners Hill red band. The "Tanners Hill red" seems to thicken toward the southeast, rather than toward the east as most of the lower red layers seem to do. This is suggestive of an encroachment from the "Altoona" delta[57] to the southeast.

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[56] J. C. Carll, Geological report on Warren County and the neighboring oil regions with additional well records. Second. Penna. Geol. Surv., Report I4, 1883. See also footnote 50.

[57] Perhaps "Maryland delta" would be more nearly geographically accurate, for it seems that it is toward this area that the secondary delta thickens. The concept of a secondary "vortex" of "Catskill" red bed encroachment is strengthened by the sections of C. R. Fettke (Subsurface Devonian and Silurian sections across northern Pennsylvania and southern New York, Geol. Soc. Amer. Bull. vol. 44, pp. 601-660, 1933) and the conclusions embodied in the 1933 paper on the Catskill in Pennsylvania by Bradford Willard ("Catskill" sedimentation in Pennsylvania, Geol. Soc. Amer., Bull. vol. 44, pp. 495-516). The concept of red "Catskill" encroaching toward the north and northwest was well recognized by H. M. Chance in his studies of the Devonian and Carboniferous of Clinton County in 1880. (Second. Penna. Geol. Surv., Report G4, p. 100, 1880.)

The Ellicott shale member marks the close of the Chautauquan series. At the top of the Ellicott shale there is an hiatus above which occurs the first member of the Conewango series, the Panama conglomerate. This disconformity is obvious throughout the southwestern counties of New York, where there is a marked change in lithology from shale to flat-pebble conglomerate, but passing westward into Erie and northern Crawford Counties of Pennsylvania, and the northeastern corner of Ohio, this disconformity is less obvious because in that region the basal Conewango tends to assume the Chagrin lithic facies, and modified faunal facies. The mass faunal change, however, at the base of the "Bradfordian" is rather abrupt.

In the Warren area the upper beds of the Ellicott shale were included in the Conewango "formation" by Butts because of the failure to recognize any Panama sandstone equivalent in the Warren section. He concluded that the Panama horizon is below river level there. The *Ptychopteria* fauna of the Venango does not extend to water level, however, at Warren, and the general thickness trends would hardly permit the Panama to be so low there.

The fauna of the Ellicott monothem is imperfectly known at present. In fact a knowledge of the fauna of the whole Chadakoin, the Girard shale and the Cuba sandstone is a very pressing need of stratigraphers who are to carry on the work of unravelling the upper Devonian snarl. The faunal list given under the discussion of the "Bradfordian series" shows Ellicott species which seem to cross the boundary into the Conewango but this represents only a very small part of the entire Chadakoin fauna. There is a greater westward facies off-set between the upper Chadakoin and lower Conewango than at any point in the Upper Devonian of this region below the base of the Mississippian. The faunal off-set is naturally in accord with the facies disconformity. The Chadakoin species which carry over into the basal Conewango are for the most part appreciably altered, thus suggesting at least a slight unrecorded interval. Many new forms appear suddenly in the midst of the Upper Devonian mutants. These new elements do not occur, so far as known, in the Chautauquan series. They are normal facies faunal elements during Conewango time, and some carry over into basal Mississippian. The following faunal list gives no indication of the coeval facies range of the species of either the Chautauquan or the Conewango and Knapp. Such facies range data is most important, but the study of facies faunas is not yet far enough along to make such analysis possible.

"Bradfordian fauna"

The "Bradfordian" series grouping implies erroneous relationship between the Devonian and the Mississippian systems in eastern North America. This matter has been discussed above. No better proof of the duality of the "Bradfordian series" exists than that shown by the faunal distribution. On the list below it is obvious that the fauna of the "Bradfordian series" of old, falls into two definite categories; few, if *any* species cross the boundary line between what are viewed as Upper Devonian and Lower Mississippian.

This list does not include all the species which have been reported from the "Bradfordian" of New York, Ohio and Pennsylvania, but does include all of those forms which have been personally, definitely identified, and whose range is known, at least in part. This species list will be greatly augmented by additional, as yet undescribed species when the faunal studies now under way are completed. The nomenclature of many of the forms is at present in a deplorable state. The list is arranged in general biologic sequence, with the more common and important forms appearing near the beginning of each biologic group.

Question marks (?) under the respective stratigraphic columns indicate that a member of the indicated species group (gens) occurs at this horizon, but that there is a serious question of specific identity. Interrogated species are believed to be mutants within a gens.

The letter "m" indicates that a definite mutant out of the recorded species occurs, and not the species *sensu stricto*.

By "x?" is meant a slight question of specific identity; forms having a very similar surficial appearance to the species listed occur at "x?" horizons, but probably more study will prove their distinctness.

When the symbols "?x" are used they indicate that the horizon at which the species occurs is only tentatively determined, but is presumably that indicated.

By "(?x)" is indicated that there is serious doubt of the stratigraphic assignment given a species by some previous worker. *Thinopus antiquus* Marsh, the purported amphibian foot-print supposedly from the western Pennsylvania Devonian is an illustration of such questionable age determination. This specimen, although long famous because of its antiquity, presumably did not come originally from the Devonian. Lithologically the matrix material of the *Thinopus* specimen is quite similar to the lower Knapp beds and the overlying "Cuyahoga" rocks. In the region south of the Allegany River, Warren County, where *Thinopus* was discovered by Beecher, the Knapp sandstone and overlying beds contain occasional iron-ball concretions and in other respects resemble this controversial specimen. Until further proof, in the form of another *Thinopus* specimen from the Devonian is offered the age of *Thinopus* will be seriously questionable.

In the list below, the vertical columns correspond to the following stratigraphic formations:

1. Upper Chadakoin (Ellicott) member
2. Basal Conewango (Panama) member
3. Amity shale member
4. Salamanca conglomerate suite
5. Saegerstown shale member
6. Woodcock sandstone member
7. Oswayo—lower Riceville member
8. Cussewago series (Knapp suite and Kushequa shale)
9. Cussewago series (Tidioute member)*

"Bradfordian" fauna list

	1	2	3	4	5	6	7	8
Lingula cf. cuyahoga Hall................		x		x				
Lingula n. sp. 1							x	
Lingula n. sp. 2..............................			x	x				
Lingula ? n. sp. 3	x							
Oehlertella pleurites Meek.................		x	x				m?	x?
Orbiculoidea allegania Hall............	x		?					

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*Space has made it necessary to refer to species occurring in the Tidioute member of the Cussewago series by the number "9" under the column 8. When "x9" is used under column 8 it indicates that the species occurs in 8 and 9.

	1	2	3	4	5	6	7	8
Orthothetes crenistria Phillips (?) (n. sp..)			x?	x?			?x	x
Strophalosia muricata (?) (Hall)	?	x	x	?				
S. hystricula (Hall)	x							
Chonetes lepidus (?) Hall	x	m?	x	x	x	x	?	?
C. scitulus (?) Hall	x	x	x		x		?	
C. setigerus (?) Hall (mut?)	x	x	x		x			
Rhipidomella? pennsylvanica Simpson					?	?	x?	x
R. leucosia var pennsylvanica Hall								x
R. burlingonensis? Hall							x?	x
Dalmanella tenuilineata Hall	x	?	?					
Stropheodonta sp	x							
Schizophoria (?) impressa Schlotheim	x	x	?					
S (?) tioga Hall	x	x?	?					
Camarotoechia contracta Hall, gens	x	x	x	x	x	x	x	x
C. c. var. robusta Hall	x							
C. allegania Williams							x	
C. orbicularis Hall	x	x?	x?	m?	x?	?	?	?
C. n. sp. 1		x						
C. n. sp. 2							x?	x
Productella lachrymosa Conrad	x	x	x	?				?
P. stigmata Hall	x							
P. bialveata Hall	x?	x	x	x	x	x	x	?
P. boydi Hall	x	x	?	?			?	
P. costatula Hall	x?	x	x	?				
P. hirsuta Hall	x?	x	x	x	?	?	?	
P. h. var. rectispina Hall		x?	x	x	x	x	x	?
Productus sp.								x
Spirifer disjunctus Sowerby, gens	x	x	x	x	x	x	x	x
S. disjunctus mut. 1. nov.				x	x	x	x	m?
S. d. mut. 2 nov.							x?	x
Spirifer n. sp.				x	x	x	?	
"S. mesistrialis" (nov.)	x	x?						
Cyrtia (?) alta (gens) (n. genus)	?		x					
"C. alta" mut. 1. nov.			x					
Syringothyris (?) chemungensis Prosser		x						
S, angulata Simpson								x
S. randalli								x
S. n. sp.								x
S. texa ? (Hall)								9
Athyris polita? Hall							x	
A. (?) angelica Hall	x	m?	?	?	?	?	m2?	?x
Rhynchospirina (?) scansa Hall and Clarke								x
Reticularia (?) praematura (Hall)		?	x				x?	
Pugnax (?) sp. (Butts)							x	
Ambocoelia gregaria Hall	x	?						
Aviculopecten tenuis Hall	x	?	?					
A. ellipticus Hall		x	x	x	x	x?	?	
A caroli Hall	x	?	?					
A celsus Hall				x	?		?	x?
A. striatus (?) Hall			x?	x	x	?	x?	?
A. aequilateralis Hall			?	x	?		?	
A. incultus Hall				x				
A. patulus Hall		x	?	x	x	x	?	?
A. cancellatus Hall	x	?						

	1	2	3	4	5	6	7	8
Gomphoceras nasutum Hall		x	?					
G. n. sp.		x		x				
''Manticoceras sp.''		x						
Porcellia (?) stebos (Hall)				x				
A. aequilatus Simpson	x							
A. n. sp. 1							x	
A. n. sp. 2								x9
Orbipecten solox (Hall)		x	x	?				
O. fasciatus (Hall)	x	?		?				
O. alternatus (Hall)	?	x	x	?				
O. 2 n. sp.				x	x			
Pterinopecten suborbicularis Hall				x	x	?	?	m?
Crenipecten amplus Hall	x							
C. winchelli (?) Hall								x
C. leoni Hall	x	x?	?	?				
C. n. sp.							x	?
Leptodesma mytiliforme Hall							x	m
L. disparile Hall							x	
L. potens Hall	x	x	x					
L. potens var. juvens Hall	x	?						
L. stephani Hall	x?	x	x	?				
L. mortoni Hall	x							
L. matheri Hall		x?	x?	x	?			
L. mentor Hall							x?	x
L. m. var. orodes Hall								x
L. m. var. biton Hall								x
L. m. var. maclurii Hall							?	x
L. m. var. rude Hall								x
L. m. var. sulcatum Caster								x
L. m. var. maximum Caster								x
L. m. var. alpha Caster							x	
L. ruedemanni Caster								x
L. cariniferum Caster							x	?
L. parallelum Simpson			x	x	?	?		
L. n. sp.								9
Pegasella ales Caster							x	
Pteronites profundus Hall	x	x?						
Prorhynchus quadratum Hall				x		x		
P. angulatum Hall				x				
P. harrisi Caster				x				?x
P. paeneplanum Caster								x
P. n. sp.				x				
P. nastum Hall				x	?	x		
Oleanella expansa (Hall)	x?	x?	x?	x?			x	
O. e. var. gamma Caster							x	
Actinopteria (?) alpha Caster		x	x					
A. (?) beta Caster		x	x					
A. (?) n. sp.		x						
Ptychopteria proto Hall		x						
P. sinuosa Hall		x	x	x	?			
P. salamanca Hall		?		x	x	?		
P. lobata Hall			x	x	?			
P. gibbosa Hall				x	x	x	?	
P. vanuxemi Hall							x	?
P. trigonalis Hall			x	x	?			
P. falcata Hall				x	x			
P. thalia Hall		?	?	x	x	?		

	1	2	3	4	5	6	7	8
P. galene Hall		x	x	x	?			
P. perlata Hall				x	x	x	?	
P. lata Hall			x	x				
P. alata Hall				x				
P. beecheri Hall				x				
P. eucrate Hall		x						
P. sao Hall		x						
P. (?) obsoleta Hall				x	x		?	
P. (several n. sp.)								x
P. n. sp.							x	
P. n. sp.				x				
Mytilarca chemungensis (?) Hall	x?	x	x	x	?			
M. simplex Hall		x?	x					
M. gibbosa Hall		?	x	x				
M. occidentalis Hall		x		x				
Mytilops praecedens Hall		x		x				
M. metella Hall	?	x	x	x				
M. n. sp.				x				
Paleoneilo cf. elongata Hall	x	?	?					
Paleoneilo (?genus) (many n. sp.)	x	x	x	x	x	x	x	x
P. perplana Hall	x							
Nucula (?) globularis Hall		x	x	x	x		?	?
Nucula (?) n. sp.				x			x	
Nucula n. sp.								x
N. umbonata Hall		x						
Grammysia communis Hall		x	x	x	?		?	
G. undata Hall		x		x				
G. duplicata Hall	?	x	x	?				
G. subnasuta Hall	?	x						
G. glabra Hall		x	x					
G. 2 n. sp.							x	
G. (genus?) n. sp.								x
Sphenotus contractus (gens)	x	x	x	x	x	x	x	x
S. clavulus Hall	?	x	x	x	x	x	x?	?
S. arcuatus Hall	x		x					
S. palmerae Caster				x?			x	?
Sphenotus cf. aeolus (n. sp.)								x
S. n. sp.				x				
Goniophora (?) curvata Simpson	?	x?	?	x				
G. (?) ruedemanni Caster							x	
Edmondia rhomboidea Hall		x	x	x	x	x	x?	?
E. phillipi Hall	x	?	?					
E. n. sp.				x				
E. (?) n. sp.								x
Pararca venusta Hall			?	x	x	x?	x	?
P. neglecta Hall							x	?
P. sao Hall				x	x	x	?	
P. erecta Hall		x		x	x	x	x?	
P. transversa Hall				x			x	
P. n. sp.				x				
P. n. sp.							x	
P. n. sp.		x						
Spirodomus insignis Beecher								x?
Paracyclas erecta Hall				x	x	x	x	?
P. ignota Hall		x		x	x	x	x	

	1	2	3	4	5	6	7	8
O. incerta Caster			x		x			
O. n. sp.				x				
Crania ? n. sp.							x	
Schellwienella chemungensis Conrad	x	x	x	m	m	m ?	m ?	m2 ?
Schuchertella n. sp.		x	x	x	x	x	?	?
Schizodus rhombeus Hall	?	x	?	x	x	x	x	?
S. chemungensis var. quadrangularis Hall	?	x	x	x	x	x	x	
S. oblatus	x							
S. n. sp.		x						
Prothyris exuta Hall			x	?	x	?		
Phthonia (?) truncata Hall	?	x						
P. nitida Hall	x	?	x					
Cypricardella consimilis Hall			x	x				
C. contracta Hall		x						
C. n. sp.				x				
Palaeanatina typa Hall		x	?	x				
P. angusta Hall		x						
P. sinuata Hall		x	?					
P. solenoides Hall		x	x	x	?		?	?
Sanguinolites (?) undulatus Hall	x	?	?					
Glossites amygdalinus (?) Winchell								x
Oxydiscus n. sp.		x						
Bellerophon (?) maera Hall	x	?	?		?			
B. macra		x						
B. n. sp.		x		x				
B. n. sp.								x
Euryzone (?) itys (Hall)	x	x						
Straparollus (?) hecale (Hall)		x		x			?	?
Macrocheilina (?) n. sp.		x						
Pleurotomaria cf. capillaria Hall		x						
Trepospira rotalia ? (Hall)		x						
Straparollus n. sp.				x				
Bembexia (?) n. sp.		x						
Loxonema (?) styliole Hall (n. sp.?)		x						
Igoceras dorsale Simpson								9
I. breve Simpson								9
I. striatum Simpson (n. sub. gen.)								9
Platyceras inaequale Simpson								9
P. mitelliforme Simpson								9x
P. varians Simpson								9x
P. n. sp. 1								x
P. n. sp. 2								x
P. erectum Hall							x	x
P. n. sp. 3		x						
P. n. sp. 4		x		x				
Gyroma (?) sp.								x
Coleolus gracilis Hall		x						
Orthoceras (?) leander Hall		x	x	?	x	?		
O. bipartitum Hall		x	x	x	?			
O. (?) warrenense Miller			?	x	?			
O. constrictum ?		x						
O. (?) consortale Beecher		x						
O. n. sp. 1				x				
O. n. sp. 2				x				
O. n. sp. 3							x	
Cyrtoceras (?) hector Hall		x	x	x				

	1	2	3	4	5	6	7	8
Hydnoceras nodosum Hall	x		?		?			?
Prismodictya prismatica Hall	x	?				?		?9
Clathrospongia abacum Hall							?	x
Thysanodictya randalli Hall				x		x	?	
Calathospongia carlli Hall								x?
Ectenodictya implexa Hall								x
Lepidesthes warrenensis Cooper								9
Hyattechinus rarispina (Hall)								9
H. pentagonalis Jackson								9
H. beecheri Jackson								9
Crinoids, many undescribed				x			x	9
Cystids, 2 undescribed							x	9
Alauroid n. gen? n. sp.								9
Asteroid n. sp.								x
Tropidocaris bicarinatus Beecher	x		x?	?				
T. interruptus Beecher			x	?	x			
T. alternatus Beecher							x	?
Echinocaris socialis Beecher	x		x?					
E. clarkii Beecher			?					
E. randalli Beecher							?	x?
Elymocaris siliqua Beecher		x	?					
Eurypteris n. sp.		x						
Earypteris n. sp.	x							
Stylonurus beecheri (Hall)				?x				
Prestwichia randalli (Beecher)				?x				
Protolimulus eriensis (Williams)		x		x				x?
P. n. sp.				x				?
Ctenacanthus randalli Newberry								x
C. chemungensis Claypole	x	x	?					
C. harrisi Caster							x	
C. n. sp.								x
Palaeoxyris randalli (Newberry)				x				
Cladodes carinatus (Newberry)				x				?x
C. coniger Hay	x							
Holonema sp.				x				
Dinichthys tuberculatus Newberry				x	x			?x
Ctenodus minutus				x?				x?
Holoptychius taylori (Hall)			x	x				
H. americanus Leidy		x		x				
H. pustulosus Newberry			?	x				
Ganorhynchus beecheri Newberry		x	?	x?				
Dipterus flabelliformis Newberry	?	x	?	x				
Rhadinchthys sp.				x				
Bothriolepis minor Newberry		?x						
Homacanthus acinaciformis Eastman				?x				
Gyracanthus sherwoodi Newberry				x			x?	x
Thinopus antiquus Marsh								(?x)
Rich Bryozoan fauna undescribed							x	x
Ostracods, unstudied			x					x
Vermes trails, several forms			x				x	x

Conewango series

The Venango stage

The Bradfordian series of Girty[58] is herein divided into two series, a Lower Mississippian, Cussewago series, and an Upper Devonian, Conewango series. The Conewango series contains two stages of deposition, the lower of which is the Venango stage of this report, and the upper the Riceville stage. The Venango age was of considerably greater duration than the Riceville.

The Venango stage[59] is made up of an alternating sequence of shales and sandstones and conglomerate lenses, in the facies provinces in which it has been studied for this report. The facies relationships of the Venango stage and the Riceville have been outlined in a previous chapter. The stage as a whole seems to grow appreciably thicker toward the east and southeast, as strata formed under encroaching delta conditions should. The thickening toward the southeast is an element in Upper Devonian deposition not adequately considered up to the present time. The work of Price[60] on the structure of the Allegany Front and a manuscript work by R. E. Sherrill[61] on the Paleozoic thickness of the Allegany trough seem to indicate that there existed a secondary delta off to the southeast of Altoona during Upper Devonian time. The Venango stage in northwestern Pennsylvania seems to embrace the confluence of the Catskill delta to the east and this southeastern, unnamed northwestward encroaching delta. Dr. Bradford Willard[62] of the Pennsylvania Topographic and Geological Survey has also been studying the southeastward thickening of Upper Devonian strata and is inclined to the view of a secondary delta to the southeast.

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[58] See footnote 22.

[59] The name "Venango" has been variously used in the past as a stratigraphic term. The "Venango oil sand group" was first defined by C. A. Ashburner in 1880 (The geology of McKean County, and its connection with that of Forest. Elk and Cameron. Second Penna. Geol. Surv., Report R. 1880) for the precise sequence here called the "Venango stage." Ashburner's term was shortened to "Venango oil sands" by J. F. Carll in 1880 (The geneology of the oil regions of Warren, Venango, Clarion and Butler Counties. Idem, Report III, 1880). In 1881 I. C. White used an abbreviated "Venango oil group" (The geology of Erie and Crawford Counties. Idem, report Q4, 1881) for Ashburner's group.

[60] Paul Price, The Appalachian structural front. Journ. of Geol., vol. 39, no. 1, 1931.

[61] Manuscript thesis for Doctor of Philosophy dissertation at Cornell University, 1933.

The Venango stage is of considerable economic importance in northwestern Pennsylvania. Its various conglomerate and sandstone members are reservoirs for petroleum throughout the oil region, where they are known as the "Venango oil sands." It is the surface development of these "oil sands" and their separating shales which are of interest here.

Panama conglomerate member.—The Venango stage was initiated by the deposition of a basal sandstone over a large area in northwestern Pennsylvania. This basal sandstone is the Panama conglomerate member. In the small village of Panama, New York, there is a prominent, and much publicized ledge of conglomerate known as "Panama Rocks.' This is the type occurrence of the basal Conewango conglomerate.

The Panama conglomerate was first described by Hall in 1843[63] when he reported it as an outlier of the "Carboniferous" conglomerate. Hall early recognized[64] his mistake and referred this conglomerate to the upper "Chemung" formation. Although Hall repeatedly mentioned the conglomerate at Panama he failed to give it the geographic name required in modern nomenclature. In 1880, J. F. Carll[65] was the first, so far as known, to designate this as the "Panama conglomerate."

The Panama conglomerate at Panama is a flat pebble, vein quartz conglomerate carrying a sparse fauna. It is approximately 100 feet thick in the type locality. This is an abnormal thickness for the member, which is usually from 15 to 50 feet thick. From the meridian of Waterford Station through Olean, the Panama is markedly disconformable upon the upper Chadakoin "formation", but from Waterford west, the Panama gradually assumes the Chagrin ("D") facies and the disconformity is less obvious, although none the less present.

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[63] See footnote 25, pp. 290-291.

[64] As in his various subsequent reports on the paleontology of New York State 1863-1898.

[65] J. F. Carll, The geology of the oil regions of Warren, Venango, Clarion and Butler Counties. Second. Penna. Geol. Surv., Report III, pp. 57-79, 1880.

The Panama conglomerate has been described as a lentil or lens at or near the base of the "Bradfordian series." It is, however, so extensive east and west that the term lentil is deceptive. The Panama is barely if any more lenticular than any coarse clastic sedimentary unit. So far as information is available the Panama (or Wolf Creek) seems to assume a red facies aspect toward the east and becomes finer and even calcareous to the west where it enters the Chagrin facies province. This is the normal nature of Upper Devonian sediments in this part of the country. The Panama since deposition has been nearly or actually completely removed by scour in some areas. The conglomerate is by no means homogeneous even where the member crosses the conglomerate facies zones (Cattaraugus and Big Bend magnafacies). It locally grades into coarse flags and shales with only the merest scattering of pebbles as in the Warren area. It appears from well sections that the member develops a shale unit in its midst in the area about Tidioute, Pennsylvania. In some places, such as the case of Allegany State Park and the territory around Salamanca, the basal conglomerate of the Venango stage is absent. This is attributed to scour along a narrow meridional belt through Salamanca. This absence of the basal conglomerate has caused much confusion in the mapping of this area.

The Panama conglomerate can be traced almost continuously by surface outcrop from northeastern Ohio through the LeBoeuf sandstone quarries on French Creek, Erie County, the Howard Quarries, Erie County, to the Dutch Hill quarries near North Clymer, New York, to the Checkered School House, at Stone Ledge, north of Blockville, New York, Chautauqua County, New York, through Panama village, across Chautauqua Lake to the hills in the Town of Ellery where it is represented by loose blocks only. It is traceable southward along Little Brokenstraw Creek to Lottsville where it outcrops at the mouth of "Lottsville well No. 1"[66]. This correlation was personally checked during the Summer of 1930. At Warren, Pennsylvania the Panama is believed to be represented by the micaceous sparsely pebbled flags immediately above the "Tanner's Hill red" band so much mentioned in conjunction with the geology of Warren. Northeast of Warren the Panama conglomerate is represented by the lower conglomerate at Pope Hollow on the Chautauqua-Cattaraugus Counties line in New York[67]. It is also recognizable in State Line Run in Warren County, Pennsylvania and Cattaraugus County, New York[68]. East and north of Warren County, Pennsylvania the basal Venango sandstone and conglomerate is known as the Wolf Creek conglomerate. The Wolf Creek conglomerate occurs at the Panama horizon[69] though is not always continuously traceable along the southern edge of the lens in the northern counties of Pennsylvania. The Wolf Creek conglomerate is well shown in the vicinity of Portville village, and on Wolf Run, near Portville on the Olean, New York quadrangle.

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[66] Second Penna. Geol. Surv., Report I4, pp. 199, 232, 233, 1883.

South of the type area the Panama conglomerate extends as a tongue into the Vanango oil sand territory where the member is known as the Venango third oil sand. The Panama member is the correlate of the Third oil sand of Tidioute, Oil City and southern Crawford County of Pennsylvania. This correlation has been checked by lateral tracing so far as possible along many new road cuts and careful paleontologic studies corroborate the conclusions from sections. I. C. White[70] came to this same conclusion from his studies in Crawford and Erie Counties. J. F. Carll[71] denied the correlation of the Panama with the third Venange oil sand. His conclusion was later corroborated by that of Charles Butts[72] and W. A. Verwiebe[73]. A careful restudy of the Allegany River exposures from northern Warren County to Oil City, Pennsylvania has rather satisfactorily proved that the second oil sand at Tidioute, which is carried below the river-level there is the Salamanca conglomerate suite, which is the same as the Wrightsville conglomerate of the Little Brokenstraw. The position of the Wrightsville conglomerate in relation to the Panama is definitely known from several occurrences about Lottsville and Wrightsville, Pennsylvania.

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[67] G. D. Harris, Notes on the geology of western New York. Am. Geol., vol. 7, pp. 164-178, 1891.

[68] Charles Butts, Description of the Warren quadrangle, Pennsylvania-New York. U. S. Geol. Surv., Geol. Atlas, Warren folio, (no. 172), 1910.

[69] The Wolf Creek conglomerate occurs in the area wherein the greatest scour and erosion (largely submarine) took place at the beginning of the Conewango epoch. As a result it is of a somewhat sporadic occurrence. Its horizon is usually present, and recognizable on a faunal basis. Some workers have been highly sceptical of the purported wide-spread condition of Panama-Wolf Creek basal conglomerate in northwestern Pennsylvania and the adjoining part of New York State. A. C. Tester and Donald Curry studied the Upper Devonian of the Allegany State Park area of New York and concluded (Mr. Curry's dissertation for a Master's degree at Indiana University and correspondence of Dr. Tester dated March 8, 1933) that the conglomerates of the Conewango series are too sporadic and non-continuous to be of any appreciable stratigraphic value. Their non-continuity is less disconcerting when the faunas of the respective conglomerates are thoroughly studied. Not uncommonly the fauna of a conglomerate carries through a sandy or shaly zone and into a coeval conglomerate beyond. The conglomerates are highly useful and important stratigraphic criteria. Lithically the various Conewango conglomerates are indistinguishable one from another, and equally undifferentiable from the flat pebble conglomerates of the Cussewago series in Warren and McKean Counties of Pennsylvania and adjacent New York. Faunally they are readily recognizable.

The fauna of the Panama conglomerate is partially shown on the preceding list of "Bradfordian" species. It is noteworthy that at the beginning of the Conewango series so many new forms make their appearance in the midst of the modified Chautauquan fauna of the Panama. Among the more important faunal newcomers are the representatives of the genera *Ptychopteria* and *Pararca*[74], although the latter is usually not common. In the Chagrin facies of the Panama in western Pennsylvania and eastern Ohio occurs the earliest known Syringothyrid brachiopod in the Eastern States. This brachiopod was described by C. S. Prosser[75] as *Syringothyris chemungensis.* It was first discovered by H. P. Cushing[76] on Mill Creek northeast of Jefferson, Ohio. The original specimens were said to occur in the Chagrin development of the Upper Chemung, precise horizon unknown. In 1932 *Syringothyris chemungensis*[77] was found in the Panama (LeBoeuf) sandstone of the Carroll quarries of Erie County[78], Pennsylvania, and specimens from the same member also are present in the Armstrong Collection from the Howard Quarries, Erie County. Fragments of *S. chemungensis* have also been found in the LeBoeuf quarries at LeBoeuf Junction[79], Pennsylvania. This species is unknown east of the Meadville meridian, and apparently is restricted to the Chagrin facies province.

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[70] Second Penna. Geol. Surv., Report Q4, p. 104, and elsewhere, 1881.

[71] **Idem**, Report I4, pp. 195-203, and elsewhere, 1883.

[72] Topographic and Geol. Surv. of Penna., Report for 1906-08, p. 192, 1908; Geol. Atlas of the U. S., Warren Folio, no. 172, p. 5. United States Geological Survey, 1910.

[73] Amer. Journ. of Sci., vol. 42, pp. 43-58, 1916; Idem., vol. 43, pp. 301-318; Idem., vol. 44, pp. 33-47, 1917.

[74] The former concept of the distribution of the genus **Pararca** solely in and above the Salamanca conglomerate horizon is definitely erroneous. The genus is present in the Panama conglomerate, but is very rare therein. It has been found at "Stone Ledge" at the "Checkerered School House," north of Blockville, near Panama, New York, and in the Carroll quarry in the LeBoeuf sandstone at LeBoeuf, Pennsylvania. (See, C. Butts, U. S. Geol. Surv., Folio 172, p. 4, 1910, for the original statement of the supposed restricted distribution of **Pararca.**)

[75] The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., 4th series, Bull. 15, p. 436, etc., 1912.

The known synonyms[80] [83] of the Panama conglomerate are as follows:

A. The LeBoeuf sandstone, near LeBoeuf Junction on French Creek, Union City quadrangle, Pennsylvania[84]. The very typical Panama fauna is present here both in the coarse sandstone and in a firestone band immediately overlying the quarry rock.

B. The Howard Quarry sandstone, southeast of Erie, Pennsylvania, Erie County[85]. The late E. J. Armstrong made a wonderfully fine collection of the fossils of this quarry rock. This collection is now at Antioch College, Yellow Springs, Ohio.

C. The Carroll Quarry rock, occurring in the Carroll Quarries at Stone Quarry Village (now abandoned), Erie County, Pennsylvania. Here again the Panama horizon is richly fossiliferous[86].

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[76] The age of the Cleveland shale of Ohio. Amer. Journ. of Sci., (4) vol. 33, pp. 581-584, 1912.

[77] This species does not belong to the genus **Syringothyris** s. s. It is apparently a member of an antecedent sub-genus of Syringothyrid, perhaps not of the same genetic line as the true **Syringothyris** of the Mississippian.

[78] Second Penna. Geol. Surv., Report Q4, p. 246 (location of site), 1881.

[79] **Idem**, p. 114.

[80] G. H. Chadwick has indicated many of these correlations in his literature studies, and it is a pleasure to give field substantiation to most of the correlations which he makes of the Panama conglomerate in his various charts and diagrams, referred to below.

[81] Chemung stratigraphy in western New York. Geol. Soc. of Amer., Bull., vol. 34, no. 1, p. 69, 1923, (abstract); and The stratigraphy of the Chemung group in western New York. New York State Mus., Bull. 251, pp. 149-157, 1924.

[82] The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 35, p. 99, 1924, (abstract).

[83] **Idem**, vol. 36, pp. 455-464, 2 figs., 1925.

[84] J. F. Carll, The geology of Warren County. Second Penna. Geol. Surv., Report I4, p. 114, 1881.

[85] **Idem**, p. 246.

D. Sandstone at the mouth of Lottsville well No. 1[87]. at Lottsville, Warren County, Pennsylvania. The identification of this sandstone was a controversial matter with the geologists of the Second Pennsylvania Survey[87]. This section is important for it is one of the very few sections in which the positions of the Panama and the overlying Wrightsville can be demonstrated.

E. "Venango third oil sand" in the vicinity of Tidioute, Pennsylvania[88]. This correlation has been discussed above, and is taken up again below.

F. Flaggy sandstone sparsely pebbled which overlies the red shale band around the foot of Tanner's Hill, Warren, Pennsylvania. Panama fossils sparsely occur in this member. This flaggy sandstone is shown in virtually all the published sections and diagrams of the Warren stratigraphy, but in practically all instances the Venango third oil sand or the Panama conglomerate have been indicated as occupying a position below river level[89] [90].

G. The lower conglomerate of the Pope Hollow section as described by G. D. Harris[91] in his discussion of the strata along this pass on the Chautauqua-Cattaraugus Counties line of New York. The faunal break at the top of the Chadakoin stage is clearly shown in this section, as Harris's "brachiopod beds" and "lamellibranch beds" would indicate, the former being the Chadakoin.

H. The conglomerate on Newel Creek and elsewhere in southern New York and northern Pennsylvania, mentioned by L. C. Glenn[92] as the Wolf Creek conglomerate seems to be a non-continuous correlate of the Panama, perhaps continuous beneath the surface in northern Pennsylvania.

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[86] **Idem**, p. 214.

[87] **Idem**, pp. 199, 232, and 233.

[88] **Idem**, pp. 278 and 344.

[89] F. A. Randall, Allegany River section at Warren, in J. F. Carll, Geological report on Warren County. Second Penna. Geol. Surv., Report I4, pp. 304-308, 1881; also pp. 297, 331 and elsewhere in the same report.

[90] C. E. Beecher, (Diagram of the geologic section at Warren, Penna.) published by J. Hall, Note on the intimate relations of the Chemung group and Waverly sandstone in northwestern Pennsylvania and southwestern New York, (abstract) Amer. Assoc. Adv. Sci., Proc., vol. 33, p. 414, (1884) 1885.

[91] Notes on the geology of southwestern New York. American Geologist, vol. 7, pp. 164-178, 1891.

[92] Devonic and Carbonic formations of southwestern New York. New York State Mus., Bull. 69, p. 986, 1903.

I. The conglomerate on State Line Run, northeastern Warren County, Pennsylvania and southern Cattaraugus County, New York which C. Butts[93] mentions as a possible equivalent of the Wolf Creek conglomerate of the Olean area.

J. The Wolf Creek conglomerate of H. S. Williams[94] and C. S. Prosser[95] as well as L. C. Glenn[92] on Wolf Creek, Allegany County, New York and elsewhere in the general area of Portville and Olean, such as "northeast of Carroltown[96]. The Wolf Creek conglomerate presumably occurs on the same horizon as the Panama but only in the northern part of its development is it presumably continuous with the Panama. The conglomeratic deposit seems to have followed an east-west strand and from this line of continuity tongues seem to extend southward into northern Pennsylvania. When viewed along the present strike they seem like dissociated lentils for which several local names may be convenient. It is not yet demonstrable that the Wolf Creek is today anywhere actually continuous with the Panama, and there is justification for retaining the name Wolf Creek for the eastern correlate of the Panama.

K. The Portville conglomerate on the Hills about Portville, New York which was mentioned and named by James Hall[97] and later described by Williams four pages after he described the Wolf Creek conglomerate. The Portville conglomerate is a synonym of the Wolf Creek because of the inadequacy of Hall's definition, and page priority of the name Wolf Creek in H. S. Williams's paper[98].

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[93] Geological Atlas of the United States. Warren folio, (no. 172,) p. 4, 1910.

[94] H. S. Williams, On the fossil faunas of the Upper Devonian: the Genesee rock section, New York. U. S. Geol. Surv., Bull 41, p. 86, 1887.

[95] C. S. Prosser, The thickness of the Devonian and Silurian rocks of western New York, approximately along the line of the Genesee River. Rochester Acad. Sci., Proc., vol. 2, pp. 5-124, 1892.

[96] L. C. Glenn, Devonic and Carbonic formations of southwestern New York. N. Y. State Mus., Bull. 69, p. 971, footnote 60, 1903.

[97] J. Hall,, Survey of the Fourth Geological District. Nat. Hist. of New York, vol. 4, 1843.

[98] See footnote 94, above; idem, p. 90, 1887.

Amity shale member.—The second member of the Venango stage (monothem) is the Amity shale of G. H. Chadwick[99]. This member was originally delimited or defined from Crawford County, Pennsylvania. The Amity is predominantly a greenish shale usually from 140-150 feet in thickness. In Ohio, where the member is represented by a Chagrin parvafacies development it is a fissile olivaceous shale carrying many thin sandy layers, fossiliferous throughout. Coming east, it is locally extremely fissile and much used for brick shale, particularly around Corry, Pennsylvania. In the Youngsville and Warren quadrangle some sandstone and flags come in at the bottom and near the middle of the fissile shale, but even at Warren the member is predominantly a soft, easily weathered, brownish-green (olivaceous) fissile shale. In the lower Amity at Warren, there occurs a local conglomerate lens which was pointed out by C. Butts[100] in the Warren Folio. This is described below.

Dutchmans conglomerate lens.—For this local conglomerate lens in the Amity shale of the Warren area the name *Dutchmans conglomerate* is proposed. This designation is taken from the run by that name which is tributary to the Allegany River in Mead Township, Warren County, Pennsylvania. There are good exposures of the conglomerate lens along this run. The Dutchmans lens is also well exposed along the Roosevelt Highway at the Mineral Well, below Stoneham, and along the railroad just west of the south end of the Glade Highway bridge across the Allegany River.

Such sporadic occurrences of local conglomerates are not uncommon in all of the Conewango formations, and may be considered a normal feature of the sedimentation in the Cattaraugus magnafacies. Such local lenses sometimes prove most annoying in the field, often necessitating an altogether disproportionate amount of time in short distance tracing of conglomerates. But these must have geographic names to make their segregation possible.

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[99] The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, pp. 455-464, 1925.

[100] Geologic Atlas of the U. S., Warren folio, (no. 172,) p. 4, 1910.

The Amity gradually assumes the "Catskill" facies as traced east, until on Kinzua Creek and at Lewis Run, and Smethport, Pennsylvania, as well as Olean, New York, it is largely represented by purple red to bright red shales and sandstones. The Amity shale carries a *Cyrtia alta*-like form in its Chagrin facies expression[101] and at Warren carries a Phyllopod crustacean fauna made famous by Charles Beecher[102]. East of Warren the Amity shale is only sparsely fossiliferous. The fauna is essentially composed of *Ptychopteria* and other pelecypods.

Salamanca formational suite.—The Salamanca formational suite is composed of three members: two conglomerates and an included shale between them. The "Salamanca conglomerate" was first described by J. F. Carll[103] in 1883 from the occurrence on the hill tops just north of the village of Salamanca, New York. James Hall had visited this "rock city" about 1840 and called attention to it in his Report the Fourth District[104]. In the Salamanca area the conglomerate is a single member, but when traced to the south the lower beds of conglomerate disappear and shale replaces them, while still further south, in Warren County and elsewhere in northwestern Pennsylvania a lower conglomerate member which carries the typical Salamanca fauna appears. It seems that this lower conglomerate initiates a suite of conglomerate deposition and therefore is justifiably linked with the better known upper conglomerate. In this report the upper conglomerate which has heretofore been known as the only representative of the Salamanca, is being considered under the new category of *suite* as the top member of a trio of members which is being termed the *Salamanca suite*. This grouping better shows genetic relationships and does not violate usage in as much as the casual worker can still speak of the "Salamanca conglomerate", meaning the medial Venango conglomerates which happen to be a unit which is a little more extensive, vertically, than was previously known. The upper member of the suite has figured largely in reports on Pennsylvania geology, especially those discussing the relationships of the Venango oil sands. The Salamanca suite, or at least the predominant member has been widely traced through the region and variously correlated with locally named conglomerates. The New York State Geological Survey published a description of the typical development of the conglomerate in the Olean-Salamanca region. (New York State Mus., Bull. 69, pp. 974-977, 1903.)

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[101] First called to the attention of the scientific world by J. Hall in 1867. (Descriptions and figures of the fossil Brachiopoda of the upper Helderberg, Hamilton and Chemung groups. Nat. Hist. New York, Paleontology, vol. 4, part 1, p. 249, pl. 43, 1867, and Idem., vol. 8, Brachiopoda, 2, pl. 26, 1894.)

[102] C. E. Beecher, Ceratocaridae from the Upper Devonian measures in Warren County. Second. Geol. Surv. Penna., Report of Progress, P3, pp. 1-22, 2 pls., 1884 and Revision of the Phyllocarida from the Chemung and Waverly of Pennsylvania. Journ. of Geol., (London), vol. 58, p. 441, il., 1902.

[103] Geological Report on Warren County, Second. Penna. Geol. Surv. Report I4, pp. 203-308, 1883.

[104] Nat. Hist. of New York, Report on the Fourth Geological District, p. 492, 1843.

Bimber Run conglomerate member.—The Salamanca conglomerate suite is usually initiated by a basal conglomerate which merits differentiation. This basal conglomerate is well developed south of Warren along the Allegany River. The name Bimber Run is suggested from its occurrence on this run and south of its mouth, the township of Watson, Warren County, Pa. The Bimber Run conglomerate is spoken of in the Pennsylvania Reports as the "Venango second "B" "sandstone or as a stray sand below the Second Venango oil sand[105]. In the Warren area the Bimber Run has been variously known, but chiefly as the "Tanners Hill quarry rock"[105a] in contra-distinction to the overlying upper Salamanca conglomerate which is locally known at Warren as the "Asylum quarry sandstone"[106]. The Bimber Run sandstone was also spoken of by J. F. Carll[107] as the "Jackson Station conglomerate" in surface outcrop near Warren. The Bimber Run sandstone is definitely lenticular and is not present much east of Kinzua or Great Bend of the Allegheny River and does not extend, so far as known from well logs, west of the Titusville meridian. It seems to be a broad tongue presumably derived from the north which is thickest along the Warren-Tidioute line and which lenses out east and west. Its maximum thickness is 100+ feet, along the Allegheny River in the type section. It is relatively barren of fossils in the type section in contrast to the very fossiliferous Pope Hollow conglomerate above. However, the typical Salamanca fauna is sparsely present.

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[105] See: Second Penna. Geol. Surv., Report I4, p. 315 **et seq.**, 1883. Unfortunately, the Pennsylvania geologists of the Second Survey were lax in the usage of the terms "A" and "B" for these divisions.

[105a] **Idem**, pp. 287, 297, 306.

[106] **Idem**, p. 317.

[107] **Idem, p. 316.**

North Warren shale member.—The North Warren shale is named from the shale sequence between the Asylum quarries at North Warren, Pennsylvania, and the Tanner's Hill quarries (now Warren reservoir) on Tanner's Hill, Warren, Pennsylvania. The best development of the shale for study is in ravines along the Allegany River on the east side, south and north of the junction of Bimber Run and the river. It is also well shown on the west side of the river, south of Irvington, above the Bimber Run sandstone. The North Warren shale member is not dissimilar in lithology to the Amity shale below, except for the increased number of yellowish sandy conglomerate lenses and the presence of the rather characteristic Salamanca fauna of large Pararcae, and *Ptychopteria beecheri,* as well as Prorhynchi and Bispiraxis cases. The thickness of this member is variable; along the Allegheny it is 35-40 feet thick and at Warren 20 feet thick. In other places it is indistinguishable: the upper and lower conglomerates lying upon each other, as in some of the Venango well logs.*

Pope Hollow conglomerate member.—The Pope Hollow conglomerate member is the upper conglomerate and sandstone of the Salamanca suite of members. It was first mentioned by James Hall,[108] in the Fifth report of the New York Geologist and first thoroughly discussed by J. F. Carll[109] in 1883 in his work on the surface correlates of the Venango oil sands. G. D. Harris[110] in 1891 gives an excellent discussion of the Pope Hollow conglomerate occurrence and F. A. Randall[111] in 1894 gives what some[112] have interpreted as the first diagnosis of the conglomerate. This sandstone is the predominant member of the Salamanca suite and is the member to which writers in the past referred when speaking of the Salamanca conglomerate. However, on the basis of the faunal association in this trio of members it seems best to show relationships to use the term Salamanca in the more comprehensive manner suggested above.

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*The commonness with which one meets with this occurrence in well-log reports is in part due to the carelessness of the drillers in reporting such a short interval of shale as usually separates the members. This is not true in all instances, however.

[108] Fifth annual report of the fourth geological district. N. Y. Geol. Surv., Ann. Rep., no. 5, pp. 171-174, 1841.

[109] Report on the Geology of Warren County. Second Penna. Geol. Surv., Report I4, pp. 180 and 203-209, 1883.

[110] Notes on the geology of southwestern New York. American Geologist, vol. 7, pp. 164-178, 1891.

The Pope Hollow conglomerate is comparable to the Panama conglomerate in its lateral extent as well as in its east and west facies gradations in accordance with normal sedimentary phenomena. Eastward, the Salamanca takes on a red facies, but is unusual in that it gradates from coarse conglomerate into coarse red highly fossiliferous marine sandstone* and then is presumably lost to us, in the present state of our knowledge at any rate, as a "Cattaraugus" red sandstone of non-marine type. Westward, the Pope Hollow conglomerate gradually becomes sandier and in Ohio is presumably one of the gas sands in the Chagrin. The characteristic fauna is unusually widely distributed, being easily recognizable from eastern Ohio to the Bradford, Pennsylvania area. In other words, the Pope Hollow conglomerate is not lenticular in the ordinary sense.

The fauna of the Pope Hollow is shown on the chart of the "Bradfordian" fauna, above. This has proved to be one of the most useful horizons in the whole Conewango series for correlation purposes. It is everywhere profusely fossiliferous. The fauna consists chiefly of autochthonous mutational types but is augmented by several forms which appear at this horizon for the first time in the eastern American section.

The Pope Hollow conglomerate has been traced carefully over most of the northwestern part of Pennsylvania and the following synonymy of named units in this region worked out. The Pope Hollow is the same member as*:

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*Note: Such a marine red sandstone occurs at the Lewis Run brick shale quarries, McKean County, Pennsylvania where it is replete with a characteristic marine fauna among which are many undescribed species.

[111] University of the State of New York, 47th annual report of the Board of Regents, p. 714, 1894.

[112] F. B. Meeks, North American geologic formation names; bibliography, synonymy and distribution. U. S. Geol. Surv., Bull. 191, p. 396, 1902.

A. Wrightsville conglomerate[113] of Warren County, Pennsylvania.

B. Miller's sandstone of Chadwick[114] of the Meadville area.

C. Faichney's quarry rock near Sugar Grove, Warren County, Pennsylvania[115].

D. Salamanca conglomerate of C. Butts at Warren, Pennsylvania,[116] L. C. Glenn at Salamanca, New York,[117] and Glenn about Olean, New York.[118]

F. Venango second oil sand (upper stratum) of J. F. Carll[119] and I. C. White.[120]

Saegerstown shale member.—The Saegerstown shale overlies the Salamanca suite of members and is overlain by the Woodcock sandstone from Warren, westward into Ohio, and by the sandy shale equivalent of the Woodcock from Warren eastward into the Cattaraugus facies province. The name Saegerstown, was proposed by G. H. Chadwick[114] in 1925 for the shale sequence until then unnamed, between the surface equivalents of the Venango first and second oil sands. It was named from the exposures along French Creek in the village of Saegerstown, Crawford County, Pennsylvania. Westward this shale gradually assumes the Chagrin facies, though carrying a fauna essentially derived from the Salamanca fauna, even into the province of Chagrin lithology. At Saegerstown the shale is of a peculiar reddish-purple hue, and was defined as Chemung by James Hall.[121]

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*See "Literature Resumé" for detailed discussion of some of the miscorrelations of this member in the past.

[113] J. F. Carll. Report on the geology of Warren County. Second Penna. Geol. Surv., Report I4, p. 203, 1883.

[114] G. H. Chadwick, The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, p. 457, 1925.

[115] See footnote 113, **idem**, pp. 220, 240.

[116] C. Butts, U. S. Geological Survey. Warren folio, (no. 172), 1910.

[117] L. C. Glenn, N. Y. State Mus., Bull. 69, pp. 974-978, 1903.

[118] **Idem.**

[119] J. F. Carll, Report of Progress in the Venango County district. Second Penna. Geol. Surv., Report I, pp. 12, 13, **etc.** 1875; and Report on the geology of Warren County. **Idem,** Report I4, pp. 203-208, 1883.

[120] I. C. White, The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, pp. 101-116, 1881.

[121] James Hall, Descriptions and figures of the fossil Brachiopoda of the upper Helderberg, Hamilton and Chemung groups. Nat. Hist. of New York, Paleontology, vol. 4, part 1, p. 249 and elsewhere, 1867.

It was this member that yielded many of the "upper Chemung" fossils from around Meadville, Pennsylvania which Hall illustrated in the Palaeontology of New York. These beds were for the most part considered "Chemung" by the geologists of the Second Geological Survey of Pennsylvania, though J. P. Lesley in 1875[122] seems to infer that they may be of "Catskill" age.

When followed eastward from Meadville onto the Warren-Tidioute meridian the Saegerstown shale becomes a typical Conewango shale. As such it is characterized by thin flaggy bands and fissile olivaceous shale in alternate sequence. Occasional thin pebble layers are found in the member at Warren.

The contact between the Saegerstown and the Woodcock sandstone is normally gradational. Along the east bank of the Allegany River, three to four miles above Tionesta, Pennsylvania the contact of the two members is disconformable. At Warren and east of there the upper limit of the Saegerstown is never clear-cut due to the eastward disappearance of the Woodcock sandstone. In northern McKean County, in the vicinity of Bradford and in the area around Olean, New York there is found a lens of conglomerate in the upper Saegerstown shale at the approximate horizon of the Woodcock sandstone. It does not appear that this conglomeratic zone, called the Tuna or Killbuck conglomerate passes into the Woodcock sandstone, but rather seems to be wholly included in the Saegerstown shale several feet below the Woodcock and, so far as known, does not extend far enough west for the two to ever occur in a single section.

The Saegerstown shale assumes the Cattaraugus purple-red facies (magnafacies "B") in the Olean area, and further to the east is represented by a parvafacies of the Tioga[123] magnafacies. The Saegerstown shale thickens very rapidly toward the east and southeast, and assumes the more landward deltaic facies in both directions. This would seem further to corroborate the contention for a confluence of two deltas making their encroachment felt in northwestern Pennsylvania in Upper Devonian time. The Saegerstown shale becomes increasingly redder as followed south from Meadville through Titusville and Oil City.

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[122] J. P. Lesley, Notes on the comparative geology of northwestern Ohio, northwestern Pennsylvania and western New York. Second Geol. Surv. Penna., Report I, pp. 95-102, 1875.

[123] This is "Oswayo" facies (Tioga) as derived from the mistaken stratigraphic usage of Fuller in U. S. G. S., Folios 92, 93, 1903. His purported Oswayo is much lower stratigraphically than the true stratigraphic Oswayo of the Olean area where it marks the close of the Conewango series. This is partially true also for the "Oswayo" of Potter County in S. H. Cathcart's report on the gas and oil in Potter County, Pennsylvania. (Topo. and Geol. Surv. Penna., Bull. 106, 1934.

In the Warren area the facies expression of the Saegerstown is that of an olivaceous to chocolate colored sandy and fissile shale. It is about 100 feet thick at Warren, Pa., and slightly thinner at Tidioute, Pa.

Tunangwant conglomerate lens.—In the upper part of the Saegerstown shale in the region about northern McKean County, Pennsylvania and the Olean-Salamanca region of New York occurs a conglomerate lens of considerable local importance. This conglomerate was first recognized as distinct from the Salamanca and the "Sub-Olean" by J. F. Carll[124] in 1883 from his tracing of the Salamanca conglomerate (Pope Hollow) in northwestern McKean County. The name "Tuna" or Tunangwant was applied to this conglomerate from exposures in New York State along Tunangwant Creek which flows northward through Bradford, Pennsylvania into New York. In 1902 Glenn[125] named the same conglomerate the Killbuck lens. The Killbuck outcrops between Olean and Portville are traceable into the type Tuna occurrence. In fact Glenn cites the type locality of the Tuna as an outcrop of his Killbuck.

The geologists of the Second Pennsylvania Survey were conversant with the idiosyncrasies of the Venango conglomerates and had very carefully traced and levelled them throughout McKean and Warren Counties. Their conclusions on this matter are for the most part very astute. The wholesale repudiation of their conclusions, especially those of Carll (and Lesley), by Glenn[125] is absolutely without factual justification. Glenn's hurried reconnaissance of the Pennsylvania area in conjunction with his New York work yielded a rich crop of miscorrelations.

Above the Tuna conglomerate is a shale sequence of the upper

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[124] Report on the Geology of Warren County. Second Penna. Geol. Surv., Report I4, p. 204, 1883.

[125] L. C. Glenn. The Devonic and Carbonic formations of southwestern New York. N. Y. State Mus., Bull. 69, p. 976, 1903.

Venango. Narrow and sporadic conglomerate lenses occur throughout this interval some part of which is presumably the eastern correlate of the Woodcock sandstone to the west. The Tuna conglomerate is quite variable in thickness; in the type section it increases from a few inches to 40 feet, Faunally it is not especially distinguishable from the whole Sagerstown member.

Woodcock sandstone member.—The Woodcock sandstone was named[126] by G. H. Chadwick in 1925 from the exposures along Woodcock Creek in the township of Woodcock, Crawford County, Pennsylvania. Prior to Chadwick's proposal the sandstone had been known as the Venango first oil sand. J. P. Lesley had indicated[127] the Woodcock Creek occurrence of the First oil sand in his Summary Report of Pennsylvania geology. His data came from I. C. White's field work[128].

The Woodcock sandstone is the top member of the Venango stage, and of all the Venango members is least satisfactorily defined at present. This is due to the fact that the sandstone is a well marked lithic unit only in the western part of the Irvineton facies province. From Warren, Pennsylvania eastward the Woodcock member is not easily distinguishable from the Saegerstown shale member below. In the type area the sandstone phase is well developed. It is a fine to medium grained buff colored sandstone containing an occasional thin pebbly layer. It maintains its sandy nature southward into the Venango oil area for a considerable distance. On the Allegany River, between Hickory and Tionesta the Woodcock is a massive sandy layer along the river banks. Northward and east, however, the sandy member gives way to flags and sandy shales, or totally disappears, by lensing out. It is not recognizable in the Warren section, nor at any point east of that meridian.

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[126] The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, p. 458, 1925.

[127] Second Penna. Geol. Surv., Summary and Final Report, vol. 2, p. 1506, 1895.

[128] The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, 1881.

In Crawford County the Woodcock marks the top of the true Venango stage. In eastern Warren County the top of the Venango is a sandy shale member, indistinguishable from the Saegerstown below. The Woodcock is variable in thickness. Typically it is 5 to 15 feet thick, eastward some of the upper beds are replaced by shale. On the Allegany River it is 5 to 10 feet thick. At the top of the Woodcock sandstone, and in the east, of the shale sequence probably coeval with it, is a disconformity, which is especially well marked toward the east.

The fauna of the Woodcock is a sparse and for the most part unstudied one. What forms have been found in it are in no way different from the fauna of the adjoining facies of the Saegerstown.

The Woodcock sandstone phase is well exposed on Dennis Run southwest of Tidioute, Pa., along French Creek on the Meadville meridian and may be represented, though doubtfully, by micaceous flags at the base of the Oswayo at Warren, Pa.

The Woodcock seems to be neither continuous nor contemporaneous with the Killbuck-Tuna conglomerate of McKean County, but is presumably a little higher in the section that this intro-Saegerstown conglomerate. The relationship between the Hosmer Run conglomerate, of the oil pit region northwest of Garland, Pa., and the Woodcock is obscure. But it appears unlikely that they are synonymous, first because the Hosmer Run conglomerate appears to be overlain by Saegerstown shale, thus being probably referable to the Tuna conglomerate horizon; second, because of the very different lithology of the two members. The Woodcock is almost universally a fine to medium grained sandstone with only an occasional sifting of fine pebbles. The Hosmer Run[129] conglomerate is a massive flat pebble conglomerate very similar to the Panama, the Salamanca suite or the Killbuck in appearance.

In Ohio the Woodcock apparently maintains its characteristic sandy facies for a considerable distance. G. H. Chadwick states very similar to the Panama, the Salamanca suite or the Killbuck that he has traced it by its "characteristic fossils" to the place where it is cut off by what he termed[130] a "summit unconformity" in central northern Ohio.

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[129] Report on the geology of Warren County. Second Penna. Geol. Surv., Report 14, pp. 248-250, 1883.

Riceville Stage

Oswayo monothem

The Riceville stage represents the closing phase of the Upper Devonian in eastern America. In 1881 I. C. White[131] differentiated a group of strata as the "Riceville formation" above the Venango first oil sand and below the Cussewago sandstone. It would seem, according to J. F. Carll,[132] that White considered the Riceville formation as the closing phase of the Devonian, for he points out the Devonian faunal aspects on at least two occasions. Chadwick definitely asserts that the Riceville is the closing stage of the Venango group. J. P. Lesley[127] for unexplained reason aligns the Riceville with the Oil Lake group (Mississippian). It so happens that there is a modicum of truth in both views.

By very careful studies, which are further discussed under "Knapp beds", below, it develops that the "Riceville", of old, is a dual formation with a medial disconformity which is of considerable importance in this area of practically uninterrupted deposition; a disconformity which seems to mark the close of Devonian and the beginning of Mississippian time.

Riceville section[133]

1.	Sandy shale and sandstone, containing many *Syringothyris* aff. *typa* (Sharpsville sandstone?)	40.	ft.
2	Limestone (?West Mead limestone) siliceous	1.	ft.
3.	Sandy shales and concealed (?Shaw's sandstone)	45.	ft.
4.	Limestone bed with *Lingula* aff. *melie*	.75	ft.
5.	Sandstone and flags (part Orangeville?)	10.	ft.
6.	Orangeville (concealed)	35.	ft.
7.	Massive gray to whitish sandstone (Corry)	12.	ft.

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[130] The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, p. 461, 1925.

[131] The Geology of Crawford and Erie Counties. Second Penna. Geol. Surv., Report Q4, p. 97, 1881.

[132] Report on the geology of Warren County. Idem, Report I4, p. 179, 1883.

[133] Compare with section in I. C. White's report on the geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, p. 192, 1881.

8.	Sandstone and flags (Upper Riceville-Knapp formation) ..	50. ft.
9.	*Syringothyris* limestone (Marvin Creek)	1. ft.
Disconformity—		
10.	Oswayo shales (Lower Riceville)	10. ft.
11.	Sandstone and flags (Lower Oswayo)	25. ft.
	Total	239.75 ft.

The old name "Riceville" is being retained in a restricted stage and monothemic sense. It is restricted to the lower division of the original Riceville[131] [132] that is to units 10 and 11 of the original section as given by White for Riceville, Pennsylvania. The Riceville, as here delimited, represents the closing phase of the Venango series of deposition as possibly White, and unquestionably Chadwick considered the whole original Riceville to do. The upper part of the original Riceville is of Knapp age, that is, basal Mississippian, according to present views in the matter. The name Riceville is not ideal for the strata here designated as such. On the Riceville meridian the Riceville strata are in the process of passing into a western facies, the Chagrin, and yet bear in their midst relics of the better known eastern Oswayo facies. The Oswayo strata in the east, in eastern Warren, and McKean Counties of Pennsylvania and of the Olean-Salamanca area of New York State have been much more thoroughly studied and more prominently exposited in literature. Historically, the name Riceville must stand for the formation, as it is here restricted, with the Devonian member carrying the name.

Oswayo shale member.—The Oswayo shale was first studied by H. S. Williams[134] in his reconnaissance of the Genesee River preliminary to his exposition of the Genesee River Section[134]. At the time of this first study the brachiopod *Camarotoechia allegania,* Oswayo index fossil was described from the "ferruginous sandstone" under the Olean (Pottsville) conglomerate. L. C. Glenn was the first to apply[135] the geographic name "Oswayo" to the formation. This first geographic designation however, implied that the Knapp shale (possibly excluding the sandstones) was to be considered as part of the Oswayo formation[136]. It is evident therefore that this original designation of the Oswayo formation was almost an exact synonym of the Riceville[137] shale of I. C. White, which is discussed above. The type section of the Oswayo member is in the Olean area on the hills along Oswayo Creek. Probably the best section in the type area is that exposed along the road to Olean Rock City from Olean, New York. Near the top of the long hill, just north of the road turning off to "Flat Iron Rock" and opposite the entrance to a lane going west toward the abandoned trolley station known as "Flat Iron Station" is the exposure. There are also excellent exposures just south of Knapp Creek, on the Bradford, Pennsylvania, road. (See section below). The Flat Iron section, while exceedingly interesting from a paleontologic view is only a small part of the whole Oswayo shale. The Olean conglomerate lies directly upon the Oswayo and over 100 feet of the member are cut out by the disconformity. The entire thickness for the New York-Pennsylvania boundary area on this meridian is shown in the Knapp Creek section.

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[134] On the fossil faunas of the Upper Devonian: the Genesee section, New York. U. S. Geol. Surv., Bull. 41, pp. 83-104, pls. I and II, 1887.

[135] The Devonic and Carbonic formations of southwestern New York. N. Y. State Mus., Bul 69, p. 978, 1903.

The Oswayo formation is laterally extraordinarily homogeneous throughout the type region, and through McKean and Warren Counties of Pennsylvania. It is everywhere a coarse arenaceous shale, brownish green to olivaceous in color, highly micaceous with thin sandstone lenses, for the most part calcareously cemented and characteristically brownish green when unweathered and tending to assume a limonitic to a chocolate brown color on the surface. The whole lithic appearance, and especially the abundance of shore-living mulluscan types and brachiopods together with an abundance of coarse carbonaceous matter suggest quiescent, near-shore conditions, if not brackish, marine-deltaic. The pelecypods are normally preserved in their life position, both valves together, vertical to the bedding planes.

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[136] **Idem,** p. 980 and plate II.

[137] G. H. Chadwick, in correspondence, (March 1933) after reading the manuscript of this report, questions this interpretation of Glenn's designation of the Oswayo as embracing the Knapp shale. But after careful restudy of the original description and in the absence of any information on the matter from Dr. Glenn himself, it still seems to the writer that the original description implied that the Knapp beds are a part of the Oswayo formation which thickened away from the type Oswayo occurrence until they were of sufficient dimension to merit a distinguishing geographic name.

Roystone Coquinite Zone

In the lower part of the Oswayo shale there is commonly found a massive coquinite[138] zone. While coquinite layers are of common occurrence throughout the Oswayo this basal zone is so persistent in northwestern Pennsylvania that it seems worthy of member designation. It has proven of great correlation value. The Roystone Coquinite zone is especially well developed along Kinzua Creek, McKean County, Pennsylvania. It is well shown in a roadside exposure on the Roosevelt Highway between Roystone and Ludlow, McKean County and on Wild Cat Creek at Ludlow. The same member is also well exposed on the highway to Olean Rock City from Olean, New York at the side road going west to the former trolly stop known as Flat Iron Station.

The coquinite is composed principally of *Camarotoechia allegania* (Williams) and a mutant form of *Sprifer disjunctus.* The Roystone coquinite has been frequently mistaken for the overlying Marvin Creek limestone[139].

The Oswayo formation has been one of the best index horizons in field tracing, for wherever it occurs the internal molds of *Camarotoechia allegania* (Williams) are found. Internal molds of this fossil are often abundant in the residual soil derived from the Oswayo shale and limestone. The Oswayo grows gradually coarser toward the east through McKean County, but has never been demonstrated as assuming the red facies. It becomes progressively less fossiliferous and seemingly uninterruptedly assumes a non-marine facies of the marine beds to the west. Plant remains are common in the Oswayo from the Allegany Park area eastward. The plants are of Carbonic affinities. · The

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[138] Term proposed by Bradford Willard, (Devonian faunas in Pennsylvania. Pennsylvania Geological Survey, Fourth Series, Bulletin G4, p. 23, [footnote,] 1932.)

[139] Described, but indefinitely located by C. A. Ashburner, The geology of McKean County, and its connection with that of Cameron, Elk, and Forest. Second Penna. Geol. Surv., Report R, pp. 68-69, 1880; Ashburner's statement restated, but not clarified by J. P. Lesley, Second Penna. Geol. Surv., Summary and Final Report, vol. 3, pt. 1, p. 1731, 1895.

Oswayo in Potter County is the non-marine facies of the McKean County marine Oswayo. In Potter County, where present, the Oswayo has usually been identified as a "Sub-Olean" conglomerate, usually as the "Pocono". In Tioga County[140],[141] the "Oswayo" substage of the "Pocono" is, according to personal correspondence with G. H. Chadwick, the eastern facies of the "Cattaraugus" of the Olean area. The Oswayo proper is cut out of the section by summit unconformity before reaching the Tioga region. This fact has been checked in the field according to Mr. Chadwick[142]. It is known to the writer that the purported Conewango[143] of the Tioga region is actually of Chadakoin age, and that by straight parallelism the "Oswayo" above the "Conewango" ought to be of Conewango or "Cattaraugus" age.

Westward the Oswayo retains its typical nature to Warren, Pa., but from Warren westward the Chagrin facies rapidly replaces the Oswayo and with this replacement, the typical, exclusively facies, fauna of the Oswayo disappears, and the Chagrin mutants of the Conewango come in, as at Riceville. Among the newly appearing forms of the Chagrin facies of the Oswayo, the typical Riceville shale, as delimited in this report, is *"Reticularia præmatura"* which does not characterize the Venango ("Conewango") facies as Chadwick seems to suggest[126]. To the south and south-southeast the Oswayo assumes a red facies, which is most pronounced south of Tidioute, Pennsylvania, and in the Venango oil region where it has been identified in the past as the "Bedford red shale"[144] overlying the Venango first oil sand, (Woodcock sandstone). A phenomenon which has been useful in gauging the relative southward proximity of the Catskill magnafacies to the Oswayo member is the pseudo-concretionary structures sometimes known as "storm rollers" which have been found to usually occur only a few miles sea-ward of the red facies. Such structures are a common feature of the Cattaraugus magnafacies[145]. At Tidioute, for example, the Riceville shale (western Cattaraugus facies) is replete with "storm rollers", and at Tionesta, seven miles to the south these beds have already partially assumed the red facies. Somewhat similar structures have been noted by J. M. Clarke in the Oneonta formation of New York, and are also well seen in the Cattaraugus magnafacies of the Enfield, just east of Ithaca, New York. They have been compared by Clarke to "Kramenzel" structure of Germany[146]. C. S. Prosser also calls attention to the presence of the same "roller" structure in the Bedford shale of Ohio, in the Cleveland area[147]. It is interesting to note that in each case the "roller" structure occurs in the non-red phase of beds which assume a red facies within a short distance.

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[140] M. L. Fuller, Description of the Gaines quadrangle. U. S. Geol. Surv., Geological Atlas, Gaines Folio, (no. 92,) 1903.

[141] M. L. Fuller, Description of the Elkland and Tioga Quadrangles. U. S. Geol. Surv., Geological Atlas, Elkland-Tioga, (no. 93,) 1903.

[142] G. H. Chadwick writes (March 5, 1933, personal correspondence), "The Cattaraugus is the 'Pocono' of Barclay Mountain, Towanda. The red beds beneath that are called 'Cattaraugus' are the (practically type) Blossburg (red) of Chadakoin-Girard age. This I have carefully checked; . . . the Oswayo does not come that far east."

[143] Caroline Heminway, Devono-Carboniferous Differentia. Thesis, (M.A.) Cornell University, 1928. (Based on studies of the area about Tioga, Pennsylvania.)

[144] Second Penna. Geol. Surv., Reports I, I5, I4, Q4, etc.

Outstanding Oswayo Localities

1. Flat Iron Station, and Rock City hill, Olean quadrangle.
2. Knapp Creek-Bradford, Pennsylvania highway road cut.
3. Ravines, Oswayo creek tributaries.
4. Smethport-Ormsby highway, McKean County.
5. Devil's Den hill, Smethport, Pennsylvania.
6. Kinzua Creek, Kushequa, Pennsylvania, Kane quarries, lower terraces.
7. Ludlow, Pennsylvania, along Roosevelt highway, just west of village.
8. Wilcox, Elk County, Pennsylvania, along Route 97.
9. Cobham Hill, Glade, Warren County, Pennsylvania.

The Oswayo thickens southeast and eastward, and thins appreciably westward. At Olean, it is from 150-270 feet thick. At

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[145] G. H. Chadwick was the first to point out the offshore occurrence of "storm rollers" in association with shoreward red beds. (Geol. Soc. Amer., Bull., vol. 42, p. 242, 1931.)

[146] J. M. Clarke, Report of field work in Chenango County. New York State Geologist, Annual Report 13, p. 538, 1894; and N. Y. State Mus., Annual Report 47, p. 732, 1894.

[147] C. S. Prosser, The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., Bull. (4) 15, pp. 26, 27, 1912.

Warren, Pennsylvania it is about 90 feet thick, and at Riceville, Pennsylvania, it is about 40-45 feet thick. At Meadville it is slightly thicker, being about 60 feet thick there and so far as evidence indicates, seems to continue into Ohio as the upper Chagrin at gradually decreasing thickness in northeastern Ohio, and presumably passes into the "Cleveland" black shale facies not far west of Cleveland. (See discussion under Knapp formation, below).

The following section illustrates the nature of the Oswayo shale and sandstone in the Olean-Bradford area. The most important feature of the section is the wonderfully fine exposure of the unconformable contact of the Oswayo and the underlying Cattaraugus facies of the Conewango.

Stratigraphic Section Along Pennsylvania Highway Number 546 Between Goodill and Duke Center, Pa.

		Thickness
28.	*Olean conglomerate.* Cap rock of the hill. Exposed back of Knapp Creek village. Concealed below.	
27.	*Knapp conglomerate.* A lower member of the Knapp conglomerates exposed by the road at Knapp Creek and below. Questionable whether this is the basal Knapp conglomerate or a sandstone in the Kushequa shale. Poorly exposed.	
26.	Concealed. (Talus and soil material bespeak Kushequa shale. Very little present. None exposed along road).	
25.	*Oswayo monothem.* Shale and sandstone, highly micaceous, olive green when unweathered. Fossils sparsely distributed. Exposed	28. ft.
24.	Flaggy, micaceous sandstone. Lenticular; cross-bedded; undulatory (rippled?) bedding; ferruginous bands and "iron stone" concretions and nodules scattered throughout.	6.
23.	Olive shale with lenticular sandstone bands varying from 1 to 2 inches in thickness	3.
22.	Sandstone, with abundant Oswayo fauna. Lithology similar to No. 21. Shale parting at base	1.
21.	Micaceous olive colored sandstone; coarse; weathering rusty; occasional limonitic concretion. *Camarotoechia allegania,* representatives of the *Spirifer disjunctus* gens, and aviculoid pelecypods relatively abundant. Bottom of first road-cut section. (No concealed interval between this and the top of the succeeding section.)	4.5
20.	Fine grained, olive, fissile shale which is bedded in a decidedly undulatory manner, suggestive of large ripple marks. Occasional sandy partings, usually not over 6 inches in thickness and always lenticular. Comminuted fossil fragments throughout. Plant remains plentiful, and 2 small coal seams (1-2 inches) exposed in section	50.
19.	Cross-bedded, much varying, sandstone; greenish color, with clay pellets and iron balls throughout. Limy layer at	

	base. Occasional shale lens in the sandstone. Fossiliferous throughout	12.
18.	Undulating, olivaceous fissile shale	1.
17.	Brownish green sandy to flaggy shales with an abundance of clay pellets	2.5
16.	a. Fine, fissile shales weathering to dark brown	9.
	b. Sandstone, olive	.25
	c. Fine, fissile, olive shale	2.
	d. Gray sandstone with clay pellets	.25
	e. Fine, fissile, laminated and rippled shale	2.50
	f. Fine grained, gray sandstone	.25
	g. Olive green shale	.50
15.	Cross-bedded greenish brown sandstone. Appears massive when fresh, but readily weathers. Shale partings; clay pellets and iron ball nodules; weathers to an ochreous color; sparsely fossiliferous throughout. Disconformable on No. 14	9.5
14.	Olive green fissile shale. To bottom of second road-cut in the descent. (No beds concealed between this item and the top of the succeeding road-cut)	15.5
13.	Micaceous olivaceous Oswayo shale. (Top of third cut.)	15.
12.	Massive sandstone lying unconformably upon the red and green shale of No. 11, below. Basal contact a very irregular surface, suggesting that the basal Oswayo is here blanketing a mound of partially eroded Cattaraugus beds. The member grades from a greenish, non-homogeneous mudstone at the base to massive grayish brown sandstone in the upper part. The entire mass is prolifically filled with triturated plant remains; several small coal seams present. (Base of the Oswayo)	18.
11.	*Cattaraugus facies of the Venango stage.* (Saegerstown shale?) Red and green shales and sandstones; shale usually red and sandstone green; becoming predominantly red near the top, whereas it is predominantly green in the lower part. No fossils	112.
10.	Green, flaggy sandstone with green shaley partings near the bottom	32.
9.	Red fissile shale and green sandy shale alternating	31.
8.	Green sandstone blotched throughout with red and chocolate (weathered purple?). Sandstone rather pure	13.
7.	Green and red shale with occasional sandy layers, mainly of green sandstone. Sandy layers contain a *marine* fauna composed of *Paraca, Oleanella* and brachiopods. The pelecypods are usually in the upright (burrowing) life position	15.5
6.	Green flaggy sandstone	7.
5.	Green and red shale (partially concealed)	12.
4.	Greenish shale, thinly laminated and containing an occasional sandy layer	15.5
3.	Massive green sandstone containing an occasional noncontinuous conglomeratic lens. The whole varying along the outcrop from flaggy to massive sandstone. The top of the unit is sharply delimited from the overlying red and green shales. Bottom not seen. (Bottom of the continuous section).	21.
2.	Red and green shale and thin sandstones indicated by soil	

and small outcrops and talus as well as short stream-bed exposures for a long distance down the section (Contact with No. 1 concealed).

1. Chadakoin ("Chemung") rocks in the valley floor.

Total.... 536.75 ft.

MISSISSIPPIAN SYSTEM

Oil Lake Series

The Oil Lake series embraces all the strata occurring from the top of the Riceville stage (Oswayo) through the Berea-Corry sandstone in northwestern Pennsylvania. In Ohio this series embraces the Bedford shale, the Cussewago sandstone, Hayfield shale and Berea; in McKean and Warren Counties of western Pennsylvania the Knapp shale and conglomerates form the lowest beds of the series. It is at present impossible to say whether the Cleveland shale of Ohio, underlying the Bedford formation is to be included in this series or not, seemingly not. (See figure 11). The relation of the Oil Lake series to the underlying Conewango series was probably better understood by the geologists of the First and Second Pennsylvania Geological Surveys than by succeeding investigators. The Oil Lake series was classified by the earlier geologists as "Pocono"[148], that is, basal Mississippian. The new set of conditions which developed in western Pennsylvania and New York at the beginning of Oswayo time and which carried over into lower Mississippian time, they recognized. They placed the Mississippian-Devonian boundary at the base of what is nown known as the Upper Devonian, Oswayo formation. Faunally the Oswayo belongs with the Devonian, as is elsewhere explained in this paper. A minor disconformity occurs at the top of the Oswayo, and above this sedimentary accumulation was renewed under much the same type of conditions as had existed during Oswayo deposition. However, a Mississippian fauna is preserved in the Oil Lake strata on the younger side of the disconformity. Mississippian fossils are absent in the Oswayo member.

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[148] By "Pocono" as here used no implication of acceptance of the correlation of these basal Mississippian beds with the eastern Pennsylvania "Pocono formation" is made. "Pocono" is a general term for basal Mississippian strata in Pennsylvania, and may at the present time be used only in this sense.

The Oil Lake series is divided into the Berea stage and the Cussewago stage, as previously outlined.

THE CUSSEWAGO STAGE

Within the Cussewago stage the sequence is so much a unity that only after closest study is it clear that there are two formations within the sequence. The difficulty is with the Hayfield shale which overlies the intimately related Knapp formational suite. The Hayfield shale is only 25-40 feet in thickness, is apparently not gradational with the underlying Cussewago sandstones, and doubtfully grades into the overlying Corry sandstone. It would seem that we really have but *one* continuous sequence here, of which the Hayfield is the closing stage. Purely as a temporary measure, indicating the uncertainty of precise relationships, herein are recognized two entities, the Hayfield "formation" and the Knapp monothem.

The Knapp Monothem

The "Knapp beds" in northwestern Pennsylvania were first denominated by L. C. Glenn[149] as a formation which apparently emerged on the Salamanca, New York, quadrangle out of his Oswayo formation of the Olean quadrangle.

As originally proposed, the name Knapp was assigned to the strata immediately below the Olean conglomerate in the Olean-Salamanca area of New York State. They were originally defined as two conglomerates with an intervening shale. Indefinite mention is made of a shale below the lower conglomerate which also belonged with the formation. As used in this report the Knapp monothem is extended downward to include the chocolate colored arenacous (Oswayo-like) shale beneath the lower conglomerate member. This shale contains the very characteristic Knapp fauna (see "Bradfordian" faunal list, above). Above the upper Knapp conglomerate member is also a shale member which is part of the monothem. This upper shale is usually eliminated by the Olean nonconformity east of Warren, Pa. The upper shale is known as the Hayfield formation.

Kushequa shale member (including the Marvin Creek limestone).—The basal member of the Knapp monothem of the

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[149] The Devonic and Carbonic formations of southwestern New York. N. Y. State Mus., Bull. 69, p. 980, 1903.

Cussewago stage is here termed the *Kushequa shale member* from the excellent exposures of the unit in the quarries of the Kushequa Brick and Tile Company at Gaffney and Kushequa on Kinzua Creek, McKean County, Pennsylvania. The Kushequa shale is also well exposed along the defunct Mount Jewett, Kinzua and Ritterville Railway approximately three miles west of Smethport, Pennsylvania. This shale has been heretofore classified as "upper Oswayo" shale or occasionally as "Knapp" shale. On the basis of the very characteristic Knapp fauna composed chiefly of *Syringothyris angulata, S. randalli, Rhynchospirina* (*Eumetria*) *scansa,* (see faunal list above), largely Mississippian types, it would seem that the Knapp should be separated from the Oswayo in which these fossil indices are lacking. The faunal evidence is materially strengthened by the existence of a disconformity between the Knapp (Kushequa) and the Oswayo shale.

The Kushequa shale is normally a dark brown, to limonitic brown, arenaceous shale. It is not materially different in lithic appearance from the Oswayo beneath, and is easily mistaken for the Oswayo in casual field examination. The Kushequa shale is fossiliferous throughout. Distributed through the member are a great many impure local limestone lenses. Near the middle of the member is a concentration of such lenses into a zone of limestones which occur through from 15 to 50 feet of the shale, and vary in individual thickness from a few inches to three or four feet. The thickest development of this zone occurs along Kinzua and Marvin Creeks, McKean County, Pennsylvania. The thicker limestones of this zone were described by Ashburner[150] as the *Marvin Creek limestone.* He was under the impression that there was but one limestone at this horizon. Rogers[151], in his final report of the First Pennsylvania Geological Survey had previously called attention to calcareous bands in his Pocono unit of northern Pennsylvania. Probably at least the McKean County development of these calcareous bands was the Marvin Creek limestone.

[150] C. A. Ashburner, Report of Progress, The geology of McKean County, and its connection with that of Cameron, Elk and Forest. Second Penna. Geol. Surv., Report R, pp. 68-76, 1880.

[151] H. D. Rogers, First Penna. Geol. Surv., Final Report, vol. 2, p. 830, 1858.

The typical development of the Kushequa shale is from eastern McKean County, where it is eliminated by Pottsville (Olean) overlap and disconformity, south to near Ridgway, Pennsylvania and non-continuously westward to the meridian of Riceville, Pennsylvania. West of Riceville the upper part of the Kushequa becomes somewhat similar in lithology to the underlying Chagrin shales. The lower Kushequa seems never to have been deposited west of Riceville. In Ohio the upper Kushequa shale is presumably represented by the upper Bedford shale. The lower Bedford appears to be the non-continuous correlate of the lower Kushequa.

The Marvin Creek limestone zone.—The persistent limestone zone in the midst of the Kushequa shale, mentioned above may best be known compositely as the *Marvin Creek limestone zone,* for it is utterly impossible to differentiate which one of the many limestones Ashburner[150] saw on Marvin Creek when he denominated it. At least two separate lenses of limestone in the Kushequa occur along Marvin Creek. They are both of similar lithology and simply represent the recurrence of similar conditions at brief intervals in the midst of Kushequa time. Taken as a whole they represent a zone.

The Marvin Creek limestones are blue gray, siliceous and decidedly reminiscent of the Meadville limestones of the Crawford series, above. They occur through a greater thickness of the Kushequa shale in the eastern part of its development than in the west. At Warren, Pennsylvania the whole zone is represented by a single fossiliferous limestone which in the past has been spoken of as a " 'Spirifer band' near the top of the Conewango"[152] and at Tidioute and elsewhere as a "Spirifer band".[153]. It is as such a band that the Marvin Creek zone is presented in the midst of I. C. White's "Riceville" at Riceville, Pennsylvania. The "Spirifers" in this case are mostly *Syringothyris angulata* and *S. randalli* in association with mutants of the *Spirifer disjunctus* gens. In the area west of McKean County where this single limestone zone which carries the earliest Kushequa fauna in the region makes its appearance, the base of the Kushequa shale ,and base of the Cussewago stage is being drawn.

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[152] C. Butts, The geology of the Warren quadrangle. U. S. Geol. Surv., Geol. Atlas, Warren folio (no. 172), pp. 4, 5, 1912.

[153] J. F. Carll, Report on the geology of Warren County. Second Penna. Geol. Surv., Report I4, pp. 279 and 289, 1883.

In addition to carrying this highly characteristic fauna the Marvin Creek limestone zone has been observed in Warren County to lie disconformably upon the underlying Oswayo shale. This nonconformity also presumably accounts for the gradual thinning of the Kushequa westward from the type area to Warren and Riceville. West of Warren in all the sections observed the shales of Kushequa age below the Marvin Creek limestone (basal bed) are absent. The Kushequa beds above the persistent Marvin Creek zone seem to carry through into Ohio in the upper Bedford with little diminution. The Marvin Creek zone is not infrequently composed mainly of large, occasionally perfect, plates and bones of fishes. This is especially true in the Marvin Creek valley and around Kushequa village. In no place is the Marvin Creek a true coquinite such as the underlying Roystone bed of Oswayo age. The Marvin Creek beds are replete with normally well preserved and not infrequently perfect fossils. The calcareous cement of the matrix does not seem to be of shell origin. Chert nodules and iron stones are usual occurrences, and in two places on Kinzua Creek in the Gaffney vicinity, flattened limonite concretions make up the main mass. Calcareous algae are abundant in the Marvin Creek zone at Kushequa village.

The Marvin Creek limestone has been traced and extensive collections made over most of McKean, Elk and Forest Counties of Pennsylvania, where it is everywhere of approximately the same lithology and of very constant faunal assemblage. Typical Marvin Creek may be seen at scores of localities, of which the following are representative:

1. Along the banks of Marvin and Potato Creeks, McKean County. This is Ashburner's type area. It seems probable that he occasionally was confused by the basal Oswayo coquinite, which also occurs in some places in the same section.

2. Kushequa (or Gaffney, as the quarry locality is called) on Kinzua Creek, just west of the Kinzua bridge, in the Kane brick and tile quarries, the locality of which is shown on the sketch map below.

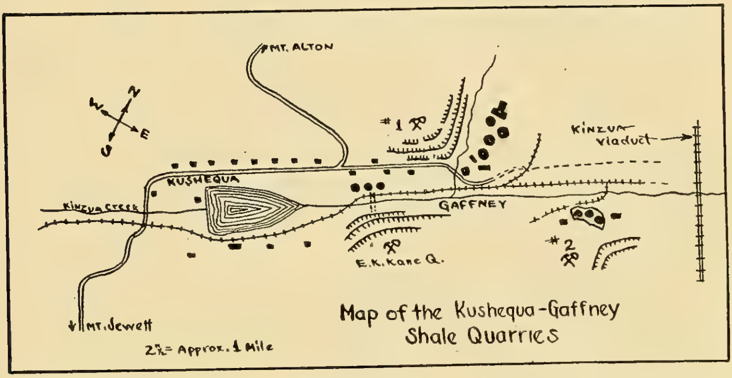

Fig. 9.—Sketch map of the quarries in the Kushequa shale at Kushequa and Gaffney, on Kinzua Creek, McKean County, Pennsylvania.

Kushequa Quarry Section

The composite section of the exposure of Kushequa shale and Marvin Creek limestone at the E. K. Kane and Kushequa Brick and Tile quarries at Gaffney, and Kushequa on Kinzua Creek, illustrates the typical nature of these beds in the type area. (See sketch map, above, for specific location of the quarries.)

		Thickness	
22.	Olean conglomerate (el. base 1940 A. T. approx.)	20.	ft.
21.	Concealed (about)	20.	ft.
20.	Knapp conglomerates and intervening shale (concealed) known by rubble only (about)	40.	ft.
19.	Concealed (shale and sandstone, predominately the latter, known from pits dug by the quarrymen [foreman's word]).	15.	ft.
18.	Blocky sandstone (top of quarry No. 1, 1932)	4.	ft.
17.	Massive, gray sandstone	10-11.	ft.
16.	Fissile shale, brown, disconformable on underlying shale..	3.	ft.
15.	Calcareous layer, siliceous, pebbly, ironstone bearing, fish bone limestone (upper phase, in this section, of the *Marvin Creek limestone* type of local limestone; here high in the Kushequa shale member). This layer is present in the east end of the south exposure of quarry No. 1. The layer		

	lenses out, becoming first a limonitic (weathered impure limestone?) conglomerate layer, pebbly at base*	3-5. ft.
14.	Shale, greenish brown. Fine, fissile	2-3. ft.
13.	Fine fissile shale, sandier above; not dissimilar in lithology to No. 14, but with marked band of limonite at the top; seemingly disconformable beneath the overlying fissile shale. This is suggestive of a soil horizon; however the gradual east and north gradation of this limonitic zone into a siliceous limestone band 2-2½ feet thick might seem contradictory. Pebbles are also present in the limonite band. The remainder of the shale of this member on the south face is barren, fine and fissile, the quarry material. This extends to the south quarry floor. In this barren interval of the south face, there comes in on the east wall, 16 feet below limonite band, a siliceous fish bone limestone, which is very hard, and seems to be largely composed of carcareous algæ or possibly Stromatopora. This layer is 2 feet thick at the angle of the quarry, and increases to over 10 feet at the extreme northeast end where a shale interval comes in, splitting it in two. In addition to this limestone in interval No. 13, the limonitic zone at the top becomes a siliceous limestone as mentioned above, and there is a limilar limestone 1 foot in thickness, 8 feet below the second limestone layer. These several limestones are well developed in quarry No. 2 and in the E. K. Kane quarry.	40. ft.
12.	Shale and sandstone	5. ft.
11.	Siliceous limestone, dense; few fossils seen, these of Knapp affinities, though common Knapp forms rare	2-3. ft.
10.	Coarse, blocky sandstone, just below the floor of the upper terrace of quarry No. 1. Oswayo-like lithology, but *Camarotoechia allegania* not noted. (Still Knapp formation)	9. ft.
9.	Fine, fissile, greenish, non-fossil bearing shale	10. ft.
8.	Sandy shale containing sporadic local conglomerate lenses	10. ft.
7.	Yellowish, conglomeratic sandstone	5.75 ft.
6.	Sandy shale, less suitable for tile than in upper quarry (in pit on hillside below upper terrace of No. 1)	20. ft.
5.	Flat pebble conglomerate lense, no fossils	7. ft.
4.	Fissile olive green shale	5. ft.
3.	Siliceous, non-fossil-bearing limestone. Similar to No. 11. (Local lens)	1.5 ft.

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*100 feet east of the angle in quarry No. 1, the item No. 15 of the above section becomes a massive sandstone, cemented with lime, 1½ foot thick, and with an iron ball conglomerate as base (1½ foot, and a fish bone conglomerate above, 2 feet thick. The item No. 17 of the above section is an important member in this sequence. It presumably marks the beginning of the Knapp conglomerate suite, for this member appreciably thickens in the eastern end of the quarry No. 1 exposure and the shale below fills crevices in the underlying shale and limestone zone to a depth of 8 feet.

2.	Olive shale	8.5	ft.
1.	Flaggy sandstone and shale, to creek bed	12.	ft.
	Total	251.75	ft.

This whole section is in the Knapp formation, and must be as nearly a complete section of the Kushequa shale in its maximum development as is exposed. The top of the Oswayo is estimated as being at about the level of Kinzua Creek at this place.

This section further indicates the nature of what has in the past been called a single limestone, the Marvin Creek. The name is useful for calling attention to the limestone lenses in the Kushequa but as far as specifically determining which of the several locally well developed lenses Ashburner had in mind, that is quite impossible. The predominant zone of limestone occurrence, however, is that in No. 13 of the above section, and of the zones in this item, that about 16 feet below the limonitic layer seems to be on the approximate horizon of the persistent *Syringothyris* band at the base of the Knapp shales in western Pennsylvania.

The former correlations[154] of the Marvin Creek with the various Meadville limestones of Crawford County was, of course, sheerest fancy, although the limestones are surprisingly similar in lithology and both series contain a great abundance of fish bones.

One of the best localities for collecting the fauna of the Marvin Creek limestone, the upper-most bed of the zone, is at Yingling-Martins brick quarry on the south outskirt of Johnsonburg, Pennsylvania. There, in the lower part of the abandoned quarry workings, is a splendid development of this limestone, replete with fossils, and of a far larger assortment than at any other of the many localities where the calcareous zone has been examined.

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[154] C. A. Ashburner, The geology of McKean County and its relation to that of Forest and Cameron. Second Penna, Geol. Surv., Report R, p. 69, 1880. Also, J. P. Lesley, Second Penna. Geol. Surv., Summary and Final Report, vol. 3, part 1, pp. 1762-1763, 1895.

Stratigraphic Section Exposed in the Yingling-Martin Shale Quarry on the Southern Suburb of Johnsonburg, Pa.

		Thickness
24.	*Johnson Run sandstone.* Highest exposure on the hill, apparently capping the hill	20. ft.
23.	Concealed, about	18.
22.	Section exposed in the hill-top quarry.	
	a. Fissile bluish gray shale which weathers to a light brown color. Replete with triturated vegetable matter. .	58.
	b. Massive light colored sandstone, varying to a coarse conglomerate. Plant remains abundant. (Olean?)	7.
	c. Fissile bluish shale, similar to a., above, containing, however, several coal seams	38.
21.	Concealed interval, from base of upper quarry to top next lower quarry. Some red shale evidently present as a sparse occurrence of red soil would suggest	160.
20.	*Johnsonburg formation.* Flaggy micaceous sandstone with shaley partings. Lepidodendron, Sigillaria and Calamite impressions relatively common	24.
19.	Massive, greenish-gray sandstone with a pseudo-conchoidal fracture. Not flaggy; in marked contrast to the overlying member	11.
18.	Greenish, fissile shale. No fossils observed	2.
17.	Lenticular zone of greenish-gray sandstone	4.
16.	Olivaceous sandy shale, sandy and muddy sandy layers scattered through the mass. Many sandy lenses	31.
15.	Platey to flaggy sandstone, olive in color; highly micaceous, regularly bedded, but heterogeneous in texture and coarseness	6.
14.	Bluish gray shale, weathering to russet brown; occasional sandy ''shells'' and concretions	5.
13.	Massive, persistent layer of large irregular grotesque concretions.	10.5
12.	Homogeneous, bluish, brown-weathering fissile shale	18.
11.	Concealed interval between the base of the middle quarry and the top of the lower quarry section	3.
10.	Sandy, greenish, micaceous shale. Top exposure in the lower quarry	21.
	Knapp formation	
9.	Moderately coarse sandstone, light colored, with limonitic stains and small iron nodules. Replete with Rhipidomelloid brachiopods. Fresh rock thoroughly indurated. Cement largely calcareous	3.
a.	Abundantly fossiliferous calcareous sandstone	1.
8.	Sandy shale, containing sandy beds and limy layers. A very brilliantly green member in the upper part of this unit is remarkably persistent in the Johnsonburg region. This green band varies from 1-1½ foot in thickness. Shales above and below the band are very similar in lithology and appearance	19.
7.	Sandstone replete with Rhipidomellæ and Syringothyris. (*Note*: The sandstones 7 and 5 of this section are lenticular, limonite flecked and occasionally contain pebbles of moderate size. Presumably Knapp in age.)	4.
6.	Olive green, brown-weathering fissile shale	3.

5.	Lenticular sandstone. Gray to buff in color. Rhipidomellæ and Syringothyris common	4.
4.	Thinly laminated, olive to brownish shale, calcareous in its lower portion	9.
3.	Highly fossiliferous argillaceous limestone. A considerable amount of carbonaceous matter present, some of which is well preserved by calcification. Limestone on weathering becomes a soft mass of limonitic residue. Syringothyris, Rhynchospirina (Eumetria), etc., abundant. Excellent preservation. (Marvin Creek limestone zone).	4.
2.	Olivaceous, apparently barren shale, exposed	1.5
1.	Talus slope to floor of quarry. Fissile shale similar to No. 2, above	20.
	Total	454.

Knapp formational suite.—Above the Kushequa shale member of the Knapp monothem comes the Knapp formational suite of conglomerates. These have heretofore been known as either the Sub-Olean conglomerate, or the Knapp conglomerate. They have usually been considered as a single conglomeratic bed, whereas they are really two conglomerate beds with a shale between. L. C. Glenn[96] in his original designation of the Sub-Olean conglomerate of the Olean, New York area as the Knapp conglomerates, described the formation as composed of two conglomerates and an intervening shale. This twofold nature of the "Sub-Olean" conglomerate is persistent over a considerable area south of Olean. Throughout McKean County and northern Elk County as well as eastern Warren County such is the case. The upper of the two conglomerates is the most extensive. It alone extends to the Ohio line as the Cussewago sandstone. Southwestward both conglomerates disappear by diminution of grain and shale replacement. Neither is present, to cite an instance, at Tidioute on the Allegany, though the upper member is over 50 feet thick at Glade, 15 miles to the northeast.

Wetmore conglomerate member or lens.—The lower conglomerate of the Knapp suite has never been given a geographic name. The name *Wetmore conglomerate* is proposed on the basis of the exposures of the member along the face of the hills between Wetmore and Ludlow, McKean County, Pennsylvania. This is the less persistent of the two Knapp conglomerates. It is found, so far as known, only in McKean, northern Forest, northern Elk, and eastern Warren Counties of Pennsylvania and in the typical Knapp area in the vicinity of Knapp Creek, New York.

The Wetmore conglomerate is a flat pebble rock which varies in thickness in an irregular manner, possibly suggestive of a broad depression filling. It is about 20 feet thick at Ludlow and about 15 feet thick at East Kane where it is exposed on the face of a brick shale quarry. The member has not been definitely traced into the Johnsonburg or Ridgway areas, though it is believed to be present as the lowest sandstone overlying the Marvin Creek zone in the Yingling Martin quarry exposure at Johnsonburg, shown above. A typical Knapp fossil fauna is universally present in the Wetmore member.

East Kane shale member.—The Wetmore conglomerate is overlain by a fissile, chocolate to olivaceous colored shale, which is highly reminiscent of the fissile greenish shale developments in the Kushequa member along Kinzua Creek. This medial Knapp shale is well exposed in brick shale quarries at East Kane, Pennsylvania. From this occurrence it is being named the East Kane[155] shale member of the Knapp formational suite. In thickness the East Kane shale is rather variable since it is dependant upon the amount of scour that anteceded the deposition of the upper Knapp conglomerate in specific areas. In some places along Kinzua Creek the East Kane shale is apparently lacking, and the two Knapp conglomerates are in disconformable contact. This explains the abnormal thickness attributed to the "Sub-Olean" conglomerate of that area in old reports.

Cobham conglomerate member.—The upper and most persistent conglomerate of the Knapp suite is being denominated the Cobham conglomerate member[156] from the exposures along ren County, Pennsylvania. This exposure of the upper and more the southeast and southwest face of Cobham Hill at Glade, War- predominant Knapp member is one of the best in the whole region. The member is about 75 to 100 feet thick on Cobham Hill in the cliff below what is locally known as the "old castle road", northeast of the present brick house known as the "brick castle" and the Cobham monument which is placed in a ledge of the member.

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[155] The preoccupied name **Ridgway shale** was suggested for this member by Caster in 1932. It is important that subsequent workers use the name "East Kane" in full. The name "Kane" is already in stratigraphic use.

[156] The name **Glade conglomerate member** was used for this member by Caster in 1932. The name is preoccupied by the Glade limestone of the Kentucky Silurian.

The Cobham conglomerate is a typical flat-pebble conglomerate, of varying texture. The size of the pebbles tends to grow smaller toward the west and the member loses its massive conglomerate appearance. From Warren west the member is composed of fine, angular pebbles, with only occasional flat pebbles. West of Warren the member is usually very loosely cemented. The angular pebbled rock ("millet grained" texture) is known as the Cussewago sandstone in Erie and Crawford Counties and eastern Ohio.

At Warren the change from a normal flat pebble conglomerate to a millet grained angular sand rock within the Cobham member is clearly shown. On Cobham Hill, at Glade, the member is a coarse flat pebbled rock, similar in lithology to the underlying Salamanca and Dutchman's conglomerates of the Conewango series. On Tanner Hill, Clark Hill and especially Cemetery Hill on the Yankee Bush upland, north of Warren, a distance of about three miles from Glade, the Cobham member has altered from a normal flat pebble rock to the typical millet-grained Cussewago sandstone type of rock. So far as field evidence would indicate, the Cobham retains the Cussewago lithology westward through Crawford County and beyond the Ohio line.

The Cobham conglomerate is the most widely developed member of the Knapp conglomerates and therefore has more largely figured in the literature. This conglomerate is the one usually referred to as the "Sub-Olean" conglomerate or the Knapp conglomerate in southern New York and the western counties of Pennsylvania which border New York State. The surmised correlations of the Cobham conglomerate member with members to the south and west are many. M. C. Read[157] early correlated the "Sub-Olean" of Pennsylvania with the Shenango sandstone of Ohio. His correlation, together with the community of conviction of the parallelism of strata lead the geologists of the Second Pennsylvania Survey into the same error. C. A. Ashburner[158] correlated the Sub-Olean with the Shenango, first on the faith of Read's correlation, and later on the evidence of his own tracing from McKean County, Pennsylvania, to Tionesta on the Allegany River in Forest County. J. P. Lesley[159] outrightly made the same correlation as also did L. C. Glenn[160] many years later. The Sub-Olean conglomerate has also been correlated with the Sharpsville sandstone. On the basis of a review of the literature G. H. Chadwick[161] suggested that the Sub-Olean conglomerate or the Knapp (i.e., Cobham) might prove to be on the same horizon as the Cussewago sandstone. Field tracing seems to substantiate this contention.

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[157] Report on the geology of the Ashtabula, Lake and Geauga Counties. Ohio Geol. Surv., Report 1, 508, 1873.

The nature of the Pottsville unconformity was not fully appreciated by the earlier workers. The relations were first brought out by Charles Butts[162] by means of his very lucid sections along the Allegany River in 1908.

On Cemetery Hill, on the "Yankee Bush" upland at Warren, Pa., the Cobham conglomerate is almost identical in lithology with the type Cussewago sandstone and it retains this facies lithology westward with no more than local pockets of flat pebbles all the way into eastern Ohio, gradually becoming finer grained. The Cussewago sandstone is fine grained, loosely cemented conglomerate. The pebbles, averaging wheat grain to pea in size are usually angular, or only slightly rounded. The sandstone is usually so incompletely indurated in outcrop that it can be shoveled like gravel. It is almost always iron-stained on outcrop and when the fresher rock is exposed it is seen to be replete with crinoid stems. Plant remains are also common in this member. The sandstone caps the many peculiarly pyramidally shaped hills along the Yankee Bush road, north of Warren and most of the cemeteries thereabouts and many to the west are located on the Cussewago facies of the Cobham conglomerate, because of the ease with which it is penetrated by simple pick and shovel.

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[158] The geology of McKean County and its connection with that of Cameron, Elk and Forest. Second Penna. Geol. Surv., Report R, pp. 66 and 67, 1880.

[159] Second Pennsylvania Geological Survey, Summary and Final Report, vol. 3, p. 1751 and elsewhere, 1895.

[160] The Devonic and Carbonic formations of southwestern New York. New York State Mus., Bull. 69, p. 981, 1903.

[161] The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, pp. 456, 457, 1925.

[162] Pre-Pennsylvania stratigraphy of southwestern Pennsylvania. Penna. Geol. and Topo. Surv., Report for 1906-08, pp. 190-204, and diagram of continuous section along the Allegany River from the New York State line to Emlenton, Pennsylvania, Idem.

The Cobham conglomerate is not of constant thickness, but despite fluctuations, is far more persistent than the term "lentil" would imply. In its wide-spread development in an east-west direction the Cobham conglomerate is similar to the Pope Hollow and the Panama conglomerates of the underlying Venango formation. The Cobham disappears to the east underneath the Pottsville summit erosion non-conformity and apparently grows finer toward the west where it probably becomes the basal member of the Berea sandstone.

As was mentioned under the discussion of the East Kane shale, above, the Cobham conglomerate ordinarily disconformably overlies that shale. In many places through McKean County, notably along Kinzua Creek, the East Kane shale is eliminated by a disconformity and the Cobham lies directly upon the Wetmore conglomerate.

The contact of the Cobham conglomerate with the shales above is very difficult to observe in the area west of Warren County, due to the absence of cuts so high on the hills. However, at Johnsonburg, the contact between the presumable Cobham and the overlying shale is conformable, but only very slightly gradational. In the Warren area the contact between the Cussewago facies of the Cobham and the overlying shale is normally gradational, or apparently so. Certainly the fauna carries through with no interruption, albeit with augmentation.

The fauna of the Cobham sandstone is essentially that of the underlying Kushequa shale. However, in the Warren area, in conjunction with the assumption of the Cussewago "millet grain" facies there is a marked increase of echinoderm elements. Crinoid fragments are so abundant in some exposures of the Cobham sandstone on Yankee Bush Hill as to make it markedly calcareous.

Hayfield monothem.—The shale immediately overlying the Cussewago sandstone on Cussewago Creek, Crawford County, Pennsylvania, was called the Hayfield shale by G. H. Chadwick[163] in 1925 from the township by that name in Crawford County. This member of Chadwick's usage included the Cussewago limestone of I. C. White[164]. Chadwick termed it the Hayfield limestone. The monothem is really composed of two parts, seemingly of member rank. The upper is the Hayfield *sensu stricto,* which includes the Hayfield limestone (here called *Littles Corner limestone*), and a lower member which enters toward the east and south which is only meagerly developed in the type Hayfield area. This lower member is being termed the *Tidioute shale member.*

The Hayfield monothem is approximately 60 feet thick in the Meadville area, and slightly less on Cussewago Creek. On the Allegany River near Tidioute the Hayfield is about 43 to 45 feet in thickness. At Glade, Warren County, on the Allegany River, the Corry sandstone has been mapped[165] as immediately overlying the Knapp upper conglomerate (Cobham). This is not actually the case, for about from 10 to 15 feet of Hayfield shale (Tidioute) intervene. This is exposed on the highway to the Tuberculosis sanitorium on Stone Hill, about one mile north of the mouth of Morrison Run, Warren County. Certainly at least 25 feet of Hayfield intervene between the two members on the hills north of Youngsville, Warren County, and perhaps this much on the Yankee Bush, north of Warren.

Tidioute shale member.—Above the Cobham conglomerate and sandstone, (the Cussewago sandstone) is a sequence of olivaceous mica-flecked shale which is in some respects the most interesting development in the northwestern region of Pennsylvania. This member carries the famous Echini fossils from near Warren, Pennsylvania, chiefly made known by R. T. Jackson[166].

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[163] G. H. Chadwick, The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, p. 463, 1925.

[164] I. C. White, The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, pp. 94-96, 1881.

[165] C. Butts, Description of the Warren quadrangle, U. S. Geol. Surv., Atlas, Warren folio (no. 172), 1910.

The *Tidioute shale member* is so-called for the excellent exposure of the unit along the Allegany River at Tidioute, and especially for the exposures along the State Highway through Dennis Run, one mile southwest of Tidioute. This seems to be the area of maximum development of the member. Here, on Dennis Run it is 23 feet thick. At Meadville the member is about ten feet thick, at Warren the thickness is in excess of fifteen feet, but the total is unknown. At Miller Farm, on Oil Creek the Tidioute member is slightly over 20 feet thick. At Tionesta, on the Allegany River the thickness is approximately the same. On Cussewango Creek, in the type section of the Hayfield shale the Tidioute member is much thinner than at Meadville, being not more than five feet thick in sections studied.

The contact between the Tidioute shale and the underlying Cobham or Cussewango sandstone is usually gradational, in the writer's experience. The Knapp fauna characterizing the Cussewago carries through into the Tidioute, but, and herein lies the basis for the segregation into a seperate monothem, there is a marked augmentation of that fauna by Mississippian genera, not present in the Knapp. The contrast is as great as between the Kushequa shale of the Knapp monothem and the Oswayo shale of the Riceville monothem, below. On Dennis Run, the type section of the Tidioute shale, the Cobham conglomerate is absent, by facies change, but the base of the Tidioute shale is exceedingly clear-cut, for it is lithically distinct from the sandy equivalent of the Cobham and the faunal augmentation is abrupt.

The Tidioute member is widely traceable on the basis of its included faunas. In the basal two feet there are sporadic developments of rich Echini faunules. Perhaps the most famous of these is that developed on Yankee Bush Hill, north of Warren, Pennsylvania. On the top of Clark Hill (Clark farm), first of the small knob-like hills rising above the common level of the Yankee Bush, on Trapezoidal Hill (so-called from its geometric shape), and Cemetery Hill about two miles north of Warren are patches of Tidioute shale which have yielded the main part of the Mississippian Echini fauna from this area[166]. These hills were extensively searched by F. A. Randall, Henry Cobham and Charles E. Beecher as well as James Hall. It is from these occurrences that virtually all of the "Waverly" fossils from Warren were derived.[167]

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[166] R. T. Jackson, Phylogeny of the Echini, with a revision of Paleozoic species. Boston Soc. Nat. Hist., Mem., vol. 7, pp. 295,292, etc., 1912.

The fauna of the basal zone of the Tidioute shale includes *Rhynchospirina scansa* and *Syringothyris angulata* and *S. randalli* of the Knapp monothem and the Echini *Lepidesthes, Paleoechinoides* and *Hyattechinus.* Crinoid columnals are also abundant. This zone is present over a large area at the base of the Tidioute member. The Echini are the determining element. They, however, are only locally common, and are nowhere abundant. The Warren locality is virtually depleted of specimens as three fragments after three weeks of intensive collecting would seem to indicate. The fauna is known from Miller Farm on Oil Creek, and Meadville, Pennsylvania as well as Warren. The zone of Echini is approximately one foot thick. At its top the Echini bed grades into a persistent fossil zone characterized by huge Platycerata belonging to the Mississippian subgenus *Igoceras.* These huge and usually grotesque gastropods are commonly abundant in the lower three feet of the Tidioute member. They occur occasionally in the stratum with the Echini, but are chiefly concentrated just above the Echini zone. *Igoceras dorsale* (Simpson), *I. breve* (Simpson), *I. striatum* (Simpson) and *Platyceras mitelliforme* Simpson, two species of productoids, several pectinoid pelecypods and several crinoids as well as many other forms make up the large fauna of this zone, most of the constituents of which are undescribed. This zone is known from exposures at Miller Farm, Tionesta, Titusville, Meadville, Corry, Garland, Tidioute, Pikes Rock Hill (Warren County), the Yankee Bush Hill, Warren, and Stone Hill, Warren County, east of Warren, Pa., and in many places between these localities.

The upper 15 to 18 feet of the Tidioute shale is usually only sparsely fossil-bearing. *Syringothyris, Platyceras, Lingula,* and many varieties of pelecypods are found by careful searching.

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[167] To cite a few references to the "Waverly" beds at Warren: C. E. Beecher, A spiral bivalve from the Waverly group of Pennsylvania N. Y. State Mus. Nat. Hist., 39th Ann. Rep., p. 102, 1885; J. Hall, Note on the intimate relations of the Chemung and Waverly sandstone in northwestern Pennsylvania and southwestern New York. Amer. Asso. Adv. Sci., Proc., vol. 33, pp. 416-419, 1885.

Hayfield shale sensu stricto.—The Hayfield shale in the strict sense of original usage, that is, the upper shale member of the Hayfield monothem is a continuation of the upper Tidioute shale, but is usually somewhat finer grained, and less micaceous. It is entirely devoid of fossils in the type area, so far as known. The Hayfield shale member is approximately 45 feet thick on Cussewago Creek, and gradually grows thinner eastward toward Warren. On the Allegany River at Tidioute the member is approximately 20 feet thick, and characterized by Knapp fossils. Among these fossils are scattered Syringothyrids, Lingulae and Aviculopectens. However, in no locality has the Platycerata-Echini fauna of the Tidioute member been found in the Hayfield member.

The contact of the Hayfield shale with the overlying Corry sandstone is most interesting for everywhere it appears to be gradational. In the Upper two or three feet of the Hayfield, especially on the Allegany River and on Oil Creek, there is an alternation of olivaceous shale and white sandstone layers which grade vertically into the base of the Corry sandstone. However, the Corry fauna does not occur in the gradational zone or below.

This condition is wonderfully clearly shown by the section exposed on Dennis Run, at Tidioute, Pennsylvania. The Upper part of a very long section running from the Salamanca suite to the Shenango sandstone, is as follows, below. It is worthwhile comparing this section as now exposed along the recently constructed highway with that of I. C. White[168] of 1881 and J. F. Carll[168] of 1883 wherein many of White's Crawford County members, especially above the Corry were recognized. Several of White's formations, especially his Meadville limestones, have not subsequently been identified in this section.

Lower Mississippian and Upper Devonian Strata exposed on Dennis Run, Tidioute, Penna.

14.	Shale and sandstone (Sharpsville?) to 1600 A. T. at first road junction on Dennis Run road....................	5.5 ft.

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[168] I. C. White, Report on the geology of Crawford and Erie Counties, (Tidioute Bluff section), Second Penna. Geol. Surv., Report Q4, p. 71, 1881; and J. F. Carll, The Geology of Warren County, (Dennis Run section), Idem, Report I4, p. 287, 1883.

13.	Massive yellowish sandstone		1.5	ft.
12.	Greenish shale, weathering brown, with sandy partings (Orangeville)		122.	ft.
11.	Sandstone and shale, few fossils, Orangeville		4.	ft.
10.	Corry sandstone, top about 1470 A. T. Buff, massive sandstone, no fossils	1.5		
	Sandstone and shaly sandstone	2.5		
	Sandstone white, tight, limy at base, fossils abundant, Corry fauna	2.	6.	ft
9.	White sandstone with olivaceous shale partings; shale preponderating in lower part. No Corry fossils present		4.	ft.
8.	Sandstone and shale, few fossils, Knapp types (Hayfield)		20.	ft.
7	Massive sandstone layer, replete with fossils, sandstone with calcareous cement. Lingula especially abundant. Leptodesmoid clams also common. *Syringothyris* fragments. (Top of Tidioute member)		3.	ft.
6.	Micaceous shale and sandstone, practically barren of fossils. (Tidioute.)		18.	ft.
5.	Sandstone, flaggy, highly fossiliferous. *Platyceras* zone at base of the Tidioute shale. Fossils well preserved. Large collection made. (Tidioute.)		2.	ft.
4.	Micaceous shale and sandstone, few fragmentary fossils. (Knapp types.)		62.	ft.
3.	*Syringothyris* limestone, ''Spirifer bed'' of White. Equivalent of the ''Spirifer bed'' at the base of the Knapp on Tanner's Hill, Warren, Pennsylvania. (Marvin Creek zone.)		3.	ft.
2.	Shale and sandstone, containing few fossils, and an abundance of ''storm roller'' structure. (Oswayo.)		110.	ft.
1.	Flaggy sandstone, showing a trace of oil (Venango first oil sand). Exposed both in the creek bed and along the Dennis Run road		25-30.	ft.
	Total		391.	ft.

This section illustrates what is being interpreted as a gradational contact between the Corry sandstone and the underlying Hayfield shale. Similar gradational contacts can be demonstrated on the Youngsville quadrangle, Pennsylvania, Warren County, one and a half miles south southeast of Pikes Rocks; at the Miller Farm section on Oil Creek, Titusville quadrangle although past stratigraphers have not emphasized the point; at Oil City, on Oil Creek, at the junction of that creek with the Allegheny River, at Rouseville, on Oil Creek, Oil City quadrangle, and elsewhere.

Littles Corner Limestone.—In the upper part of the Hayfield shale member occurs a rather persistent siliceous limestone similar in lithology to the more pure developments of the Marvin

Creek limestone zone in McKean County, and also similar to the Meadville limestones in Crawford County. This limestone, which in the past has been known simply as the Cussewago limestone[169] and since G. H. Chadwick[170] applied the name Hayfield to the enclosing shale, the "Hayfield limestone," may fittingly be called the *Littles Corner limestone* from the village by that name in Cussewago valley, Crawford County, Pennsylvania. It is well exposed on the old Line Farm, one and a half miles below Littles Corner, and at the abandoned Bartholomew quarry, one mile above Littles Corner, and along the road just below the quarry, as well as across the creek from the quarry.

The Littles Corner limestone in the type occurrence in Hayfield township is a very hard, bluish-gray siliceous limestone containing no macroscopic fossils so far as could be determined from examination at many localities. When fractured it has a somewhat glassy lustre similar to the Meadville limestones.

This limestone, like the various overlying Meadville limestones has been more widely "traced" in the past than its actual occurrence would warrant; any limy layer whether similar in lithology or demonstrably coeval, as long as it occurred somewhere below what the stratigrapher was prone to call Berea, was unequivocally called "Cussewago limestone".[171]

The position of the Littles Corner limestone to the Berea (Corry) is somewhat variable, but it usually occurs from 15 to 20 feet below the Corry base. In one or two instances it has been reported immediately below the Corry as in the Brewery gully[172] at the Iron Bridge in Meadville, Pennsylvania. This exposure is now covered, and must stand on record. Other reports of the limestone immediately below the Corry as in the case of some of the occurrences mentioned by W. A. Verwiebe[173] are seemingly miscorrelations of the fossil zone at the base of the Corry which in some places is very limy, for the Littles Corner member. The Littles Corner limestone is in reality somewhat restricted in distribution and has personally never been identified far from the type area.

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[169] I. C. White, The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, p. 94, 1881.

[170] The Chagrin formation of Ohio, Geol. Soc. Amer., Bull., vol. 36, p. 463, 1925.

[171] I. C. White, to cite but one instance, correlated the Cussewago limestone with a "Spirifer bed" 350 feet beneath the Olean conglomerate at Garland, Pa. (Second. Penna. Geol. Surv., Report Q4, p. 94, 1881.) This "Spirifer bed" is apparently on the Marvin Creek limestone horizon.

[172] **Idem**, p. 164.

BEREA STAGE

Berea sandstone formation

As is explained under the discussion of the Ohio-Pennsylvania correlation, later in this report, the Berea sandstone is commonly believed to be a tri-partite formation, basally composed of a sandstone which is the equivalent of the Cussewago sandstone of western Pennsylvania (i. e., Cobham of Warren County, Pennsylvania), medially of a shale interval which decreases in thickness eastward, (the Hayfield shale interval), and at the top of a massive gray sandstone, the main quarry rock of the Berea, which continues into Pennsylvania as the Corry sandstone, (the "Venango first oil sand" of Verwiebe[173]). Available information would not disprove this correlation, G. H. Chadwick[163] notwithstanding.

Corry sandstone member.—Over the whole northwestern corner of Pennsylvania the Hayfield shale is overlain by the Corry sandstone[174] which is being correlated with the Upper true Berea sandstone of Ohio. The Corry is named from the exposures in the old Colegrove quarries on the hill top south of Corry, Pennsylvania where formerly extensive building stone quarrying was carried on. The Corry is a grayish white sandstone, very pure, and containing fossils only in the lower foot or foot and a half. It is normally about 15 feet thick from Corry to the Ohio line and from there thickens steadily westward. East of Corry the sandstone gradually grows thinner by non-deposition of the upper beds (or subsequent erosion?) until it disappears at a "feather edge" near Big Bend on the Allegheny River. At Warren, the Corry is about 4 feet thick; in the Youngsville area to the west it is about 10 feet thick. At Tidioute it is approximately 5 feet thick, and at Oil City it is of practically the same thickness. The eastern line of disappearance would be drawn approximately from Big Bend southwestward between Tionesta and Marionville, Pennsylvania. East of that line it is unknown, and presumably was not deposited. The basal bed of the Corry, that is, the fossil zone at the base, is the most persistent. It is an almost perfect index to the presence of this member and is found to within less than a mile of the line indicated.

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[173] The Berea of Ohio and Pennsylvania. Am. Journ. Sci., vol. 42, p. 57, 1916.

[174] I. C. White, Geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, pp. 92-94, 1881.

*Fauna of the Corry sandstone.**

Pterinopecten alternatus (Simpson)
Aviculopecten aequilatus Simpson?
A. aff. patulus Hall (n. sp.?)
A. aff. cancellatus Hall
Aviculopecten 2 n. sp.
Crenipecten (?) n. sp.
Leiopteria (?) cornelli Caster (n. gen.)
Leptodesma (?) n. sp. (n. sub. gen.)
Ptychopteria (several n. sp.)
Myalina (?) n. sp. (n. gen.?)
Mytilarca n. sp. (n. sub. gen.?)
Edmondia n. sp.
Grammysia (?) n. sp.
Sphenotus (?) n. sp. (n. gen.)
Sanguinolites senilis Herrick
Spathella (?) n. sp. (n. gen.)
Pararca neglecta Hall
Pararca n. sp.
Paleoneilo n. sp.
Cypricardinia aff. consimilis Hall
Elymella (?) chadwicki Caster (n. gen.)
Straparollus aff. robertsi White
Straparollus n. sp.
Bellerophon sp.
P. dorsale (?) Simpson
Platyceras 2 n. sp.
Pleurotomaria sp. (gen. sp.?)
Gyroma (?) n. sp.
Orthoceras (?) 3 species
Tropidodiscus aff. cyrtolites Hall
Porcellia n. sp.
Conularia sp.
Crania n. sp.
Lingulodiscina sp.
Lingula cf. waverliensis Herrick

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*This list does not include all the forms known to exist in the Corry sandstone and present in the collection made during the course of this study. There are several undescribed species and new genera which will be fully described in subsequent reports.

Lingula sp.
Orbiculoidea (several n. sp.)
Rhipidomella n. sp.
Schuchertella aff. desiderata Hall and Clarke
Schuchertella sp.
Chonetes sp.
Chonetes n. sp.
Chonopectus aff. fishcheri Hall and Clarke
Chonopectus (?) sp.
Camaroteochia contracta (mutants)
C. heteropsis (?) Winchell
C. metallica (?) White
Retzia (?) n. sp.
Cyrtina triplicata Simpson
Tetracamera (?) sp.
Paraphorhynchus mediale (Simpson)
P. striatum (Simpson)
P. girtyi Caster
Productella n. sp. (gen.?)
Productus arcuatus (?) Hall
P. aff. levicosta (mutant)
Productus ovatus Hall
P. ovatus (n. s. sp.)
Productus n. sp.
Strophalosia (?) n. sp. (n. gen.)
Ethridgina (?) sp.
Spirifer disjunctus gen (mutants)
S. marionensis (?) Shumard
S. allegheniensis Caster
Spirifer n. sp.
Syringothyris texta (?) (Hall) (mutant)
S. aff. carteri (Hall)
S. angulata Simpson (mutant)
S. extenuata (?) (Hall)
Syringothyris sp.
Composita (?) sp.
Athyris aff. lamellosa (L'Evéille) (n. sp.)
Cliothyridina n. sp.
Reticularia (?) praematura (?) (Hall) (n. gen., n. sp.)
Rhynchospirina (?) aff. scansa (Hall) (n. sp.)
Clathrospongia abacus Hall
Dictyospongia (several genera and species)
Thysanodictya sp.
Ectenodicya implexa Hall
Rhombopora (several species, many other genera)
Crinoids, Asteroids and Ophiuroids, Echinoid fragments
Phyllopod crustacean
Trilobite (gen. sp.?)
Ostracodes (unstudied)
Fish bones commonly found (several genera, 2 n. sp.)
''Spiraxis'' sp.

From this faunal list, incomplete though it is, it seems to one familiar with Mississippian and upper Devonian faunas that here is an early Mississippian assemblage. Yet, many of these species and most of the genera are found in the underlying Hayfield monothem.

Correlation of the Corry Sandstone.

As was pointed out by J. F. Carll[176] and J. P. Lesley[176] the Corry sandstone is the "third mountain sand" of the oil wells of southern Crawford, Warren and Venango Counties. The "mountain sands" are described by J. F. Carll[177] and I. C. White[178]. The Dennis Run section given above illustrates the relationship of the mountain sands to the Venango oil sands. In the Tidioute and Tionesta area, as well as on Oil Creek the "mountain sands" from top to bottom are: Olean conglomerate, (assuming that the basal Pottsville conglomerate of northwestern Pennsylvania is the Olean, an undemonstrated correlation,): "first mountain sand"; Shenango sandstone, (the "sandstone in the Cuyahoga" of C. Butts[179]) : "second mountain sand"; and the Corry sandstone, ("Berea sandstone", and the so-called "Venango first oil sand" of W. A. Verwiebe,) : "third mountain sand". While this is the correlation between the "mountain sands" and the named formations in the area of original designation, it by no means follows that the first three massive sandstones struck in wells in the "oil region" elsewhere, and termed the "mountain sands" are the same. The Pottsville overlap admits successively higher sandstones toward the south and southwest. Without attempting to unravel the web of correlations elsewhere, in the Venango area, from Tidioute to Oil City, and from the Allegany River through Titusville, the Corry sandstone is the unit designated the "third mountain sand".

To summarize the correlation of the Corry sandstone: the Corry sandstone was correlated with the Pithole grit of northern

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[175] The geology of the oil regions of Warren, Venango. Clarion and Butler Counties. Second. Penna. Geol. Surv. Report I3, pp. 91-104. 1880.

[176] Second Penna. Geol. Surv., Summary and Final Report, vol. 3, part 1, p. 1771, 1895.

[177] Report of progress in the Venango oil district. Second Penna. Geol. Surv., Report I, pp. 1-49, 1875.

[178] The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, p. 67, 1881.

[179] Pre-Pennsylvania stratigraphy of southwestern Pennsylvania, Penna. Topo. and Geol. Surv., Report for 1906-1908, pp. 190-204, and diagram. 1908.

Venango County by J. F. Carll[180]. After examining the Pithole Creek section it would appear that this correlation is correct. Carll correlated the Berea sandstone with the Pithole grit.; the Corry seems to be at least a partial correlate of the Berea, as will be explained below.

The Corry sandstone is also the basal sandstone of the Oil Creek Lake group of I. C. White[178] (the Oil Creek group of J. P. Lesley[181].). White's Oil Lake group corresponded almost exactly to Carll's[177] "Barren oil measures of Venango" or the Mountain sand group.

The "Venango first oil sand" of W. A. Verwiebe[182] is the Corry sandstone; the true Venango first oil sand is well shown in the Dennis Run section, above. This is some distance below the Corry sandstone.

The Corry sandstone is the "Berea sandstone band" of Charles Butts[183] in the Warren area. It is also the "Berea sandstone" of G. H. Girty[184] from the basal bed of which he assembled an extensive fossil collection in the early part of this century.

The relation of the Corry sandstone to the true Berea grit of Ohio is as yet obscure. It would appear that the upper Berea sandstone of Ohio is continuous with the Corry sandstone. A very careful field study of this matter was undertaken in 1932 and despite the difficulties of widely spaced outcrops between the Pennsylvania line and the typical Berea of Ohio, it would appear to the writer that G. H. Girty[184], C. S. Prosser,[185] and W. A. Verwiebe[182] were correct in their correlation of the upper part of the Berea sandstone with the Corry sandstone, while the writer leans to their correlation of the lower Berea with the Cussewago shale (Hayfield) and Cussewago sandstone this correlation is necessarily less positive than the former. This matter is discussed later under the subject of Correlation.

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[180] The geology of the oil regions of Warren, Venango Clarion and Butler Counties, including surveys of the Garland and Panama conglomerates, Second Penna. Geol. Surv., Report I3, pp. 91-97, 1880.

[181] Editorial notes in Second Penna. Geol. Surv., Report Q4, pp. ix and 67, 1881.

[182] The Berea formation of Ohio and Pennsylvania. Amer. Journ. Sci., vol. 42, p. 47, and elsewhere, 1916.

[183] The geology of the Warren quadrangle, U. S. Geol. Surv., Geol. Atlas, Warren folio, (no. 172), 1910.

[184] Geologic age of the Bedford shale of Ohio, N. Y. Acad. Sci., Annals, vol. 32, p. 304, 1912.

[185] The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., Fourth series, Bull. 15, pp. 95-97, etc. 1912.

These correlations are offered as the results of detailed tracing of the Corry sandstone throughout northwestern Pennsylvania on the basis of lithology and fossil fauna. The lithology of the Corry sandstone is unusually constant throughout the area extending from Great Bend on the Allegany River in eastern Warren County to the Ohio line, and from the most northerly outcrops in the vicinity of Corry, to Oil City, Pennsylvania. The most dependable criterion in field tracing was the always present fossil zone at the base of the Corry.

This fossil zone yields the only fauna known from the Corry. See faunal list above. The Corry fossil band is one of the most characteristic features of all the steep slopes along the Allegany River from Kinzua to Oil City. It is well developed at the Colegrove quarries at Corry, the type occurrence of the formation. It so happens that in the freshly quarried rock the calcareous zone of fossil shells is not obvious since it is of the same light gray color as the sandstone. However, during the fifty years of operation of the Colegrove quarries the basal layer has been discarded as poor building rock. A large pile of this discarded material can still be seen in the abandoned quarries. Upon weathering the fossil shells stand out in clear-cut relief. This may explain why some earlier workers failed to note the fossil zone in the type outcrops of the Corry.

Carll noted[186] the fossil zone in the lower Corry and called attention to it in the description of western Warren County. It seems difficult to reconcile subsequent disparagement[182] of his conclusion in face of the evidence in the Colegrove quarry.

Some of the outstanding localities for the study of the Corry sandstone in addition to the type locality at Colegrove quarry, which is still one of the best, are:

1. Cross roads, in the village of Grand Valley, Warren County, where the road side and fields contain a great abundance of the characteristic light gray sandstone replete with fossil molds stained dull red.

2. Road-cut along the Thompson Creek road, one and one-half mile northeast of Hydeville, Titusville quadrangle, Pennsyl-

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[186] Second Penna. Geol. Surv., Report I4, p. 273, 1883.

vania. Fresh exposure in 1932, excellent material, almost identical in appearance to the type occurrence.

3. Pit Hole Creek, Tionesta quadrangle, just north of the highway bridge across the stream. Fossil collection.

4. One half mile south of Nuttle's Rock, Youngsville quadrangle; a few feet above the 1800 foot contour on the south road. Very fossiliferous, typical Corry sandstone. Best exposure in the Warren region.

5. Dennis Run, Tidioute, Pennsylvania. Occurrence shown in the Dennis Run section of this report.

6. Cobham Hill, Glade, Warren quadrangle, Pennsylvania. No exposure, but the weathered limy layer of the basal Corry scattered in abundance on a terrace a little above the Cobham conglomerate. Also similarly occurring along the same hill on the north side of the river to a point opposite Big Bend, on the Allegheny River, and in the same manner south of the Allegheny River on Stone Hill north of Dutchman's Creek.

7. Morrison, Sill and Grunder Runs, south of the Allegheny River, Warren quadrangle. Loose blocks of the fossiliferous Corry choke the streams. In place on the upper reaches of Sill Run.

8. In the Village of Allegheny Springs, Youngsville quadrangle, loose blocks of Corry sandstone are extremely abundant.

9. Fifteen feet above the railroad bed, at the first semaphore below the viaduct over the railroad at Rouseville, Pennsylvania, on Oil Creek, Oil City quadrangle. This is an important occurrence in the tracing of the oil sands toward the south.

10. At the mouth of the N. Y. Central Railroad tunnel and along the highway on the west side of Oil Creek; and on the south nose of the hill between Holiday Run and Oil Creek, about 8 feet above the road, in the borough of Oil City, Pennsylvania.

11. At Tionesta, Pennsylvania, west side of the Allegheny River, along the railroad, just north of the river bridge, and along the highway up Tionesta Creek, between the villages of Tionesta and Peters Run the Corry stands out in bold relief; fauna not well developed.

Crawford Series*

The strata above the Corry sandstone and including it, usually have been variously grouped in the past, but the uniform procedure has been to split the sequence into at least two "formations" or "groups" in Pennsylvania. Ohio geologists have been a little broader in their concepts, and included all of the strata from the Corry to the Shenango in their Cuyahoga "formation". For the time being, until further study of the supra-Berea sequence in Pennsylvania has been prosecuted in more detail, it is inadvisable to refer the Pennsylvania rocks of this epoch to any named Ohio series. In this report the abandoned Pennsylvania series name, Crawford has been resurrected to embrace the sequence above the Berea, including the Shenango "formation". The Crawford series of Pennsylvania seems naturally to be divisible into two groups of strata, each of which apparently merits monothemic rank. These are the *Meadville monothem* and the *Shenango monothem.*

MEADVILLE STAGE**

MEADVILLE MONOTHEM

The Meadville monothem is proposed to include the Sharpsville "formation" of I. C. White and also his original Meadville "group". It seems, after careful study, that the strata below the Shenango sandstone to the top of the Corry sandstone are so closely related environmentally and faunally as to necessitate some recognition of their genetic relationship. Wherefore their assignment to a single monothem for which White's name Meadville is as appropriate as any other. Several members comprise the Meadville monothem.

The Orangeville shale member.—This shale formation was originally described as a distinct formational unit in Crawford

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*Note: If relationship can be better shown, and evidence offered to support this arrangement, there can be no objection to considering the Crawford as a **subseries** of the Kinderhook series. The Crawford grouping seems genetically incontestable. The present interest lies in the recognition of this fact. The relation between the Kinderhookian and the Crawfordian is yet to be determined.

**Note: In accordance with the procedure previously outlined in this report, the International "stage" is recognized as the next subordinate classificatory degree below "series" but when a stage is not subdivisible into monothems, the sequence within the stage automatically becomes a monothem and the stage may be described as "monotypic".

County's stratigraphy by I. C. White in 1881[187]. It was defined as the 100 to 120 feet of olive shales at the bottom of the Cuyahoga formation of Ohio. It is of rather constant thickness throughout Crawford County and gradually grows coarser eastward, though it is so soon cut out to the northeast that little is known about its trend in that direction.

Lithically the Orangeville shale is not markedly different from the Hayfield shale below the Corry and the Harvest Home shale ("Meadville shale") in the upper part of the Meadville monothem. The exact identification of the Orangeville shale east of Titusville is difficult because of the eastward entrance of flags in the member and an accompanying diminution of the fauna. It has been recognized in many places about Titusville. Church Run and Bates Hollow as well as the hillside along the Pine Creek road to Enterprise all show good exposures of typical Orangeville. There is a limited exposure on the road to Grand Valley, about one mile northeast of Enterprise. The long rock section from Good Will Hill to Grand Valley along the state highway exposes the Orangeville in a nonfossiliferous phase; and this despite the typical nature of the shale.

At Tidioute, on the Allegheny River, the Orangeville is present above the Corry (or presumably so). The shale overlying the Corry sandstone has a superficial Orangeville appearance, but it is barren of fossils. It is on the basis of the presence of the Corry sandstone in contact with a very suggestive shale and flag sequence in Dennis Run at Tidioute that one feels reasonably safe in recognizing the Orangeville in this section. Inasmuch as Dr. I. C. White was mistaken in this Corry correlation in this section it would seem logical that likewise his Orangeville was mistakenly identified. Certainly this is true of the higher members. (Q4, p. 71).

At Warren, Pennsylvania, the Orangeville, if present, and there is no good basis for questioning its presence, is part of the sequence represented on the geologic map[68] as "Cuyahoga formation". This formation is seen in very few exposures in the Warren vicinity, and is universally barren as far as known. East of Warren the Orangeville (or lower Cuyahoga, whatever that may be) is cut out of the section by Pottsville erosion. To the south, however, the Orangeville is quite probably represented by massive and flaggy sandstones carrying only plant fossils. Such is thought to be the case from Tionesta Creek east to the Clarion River. This last suggested correlation is yet to be substantiated.

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[187] Report on the geology of Crawford and Erie Counties. Second Penna. Geol. Surv., Report Q4, pp. 89-90, 1881.

It is impossible at present to establish the relationship of the Sunbury shale which overlies the Berea sandstone in Ohio to the Orangeville occupying the presumed same position in Pennsylvania. In no section known is there a suggestion of the transformation of the Orangeville into a black shale facies such as marks the Sunbury shale. Exposures are absent in the critical area between the known distribution of the two formations. Their continuity is possible, but unproven.

The fauna of the Orangeville shale is imperfectly known. No large collections have been made and few, if any forms definitely described from the member. In the area about Meadville, along French Creek and Oil Creek the Orangeville is very fossiliferous. The number of species is known to be nearly a hundred; most of these are new. Inarticulate brachiopods and fish bones are common; pelecypods locally common; likewise *Syringothyris* and *Spirifer;* also *Conularia.*

*"Sharpsville formational suite"**

Above White's Orangeville shale and within his "Meadville group" was the Sharpsville "formation". This was made up of a basal sandstone member, a thin limestone member, a medial sandstone member, and an upper limestone member of somewhat sporadic nature. The interesting thing about this Sharpsville "formation" is the gradational nature of all its beds, and its basal intergradation with the Orangeville. There is no clear basis for segregating it formationally, especially inasmuch as it is so perfectly a part of the sequence. Perhaps it is fairest to the past to consider the "Sharpsville formation" of old as a

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* In as much as the treatment of the Cussewago "formation" earlier in this report is in such marked contrast to the present treatment of the Sharpsville it should be indicated that the cases are not at all similar when closely compared. In the case of the Cussewago there was described a tripartite category which the field facts substantiate as a unit, whereas the Sharpsville and Meadville "formations" have their "members" interdigitated.

"formational suite". However, for the present the name "Sharpsville" is definitely being reserved for the sandstone only.

Shaws sandstone member.—It is suggested that the basal member of the "Sharpsville formation" of I. C. White which he differentiated[188] as the "Sharpsville lower sandstone", henceforth be known as the *Shaws sandstone* member, from the good exposures of the unit in the ravine behind the Shaws brick school house on the Meadville-Franklin highway, Meadville topographic sheet. The thickness of the sandy series is 8 to 10 or 15 feet in this area, and in general lithic nature it is practically identical with the sandstone in the middle part of White's "Sharpsville formation". The Shaws sandstone can also be seen in and about Meadville, in and about Oil City and Franklin and about Sharpsville, Pennsylvania. No fauna is known.

West Mead limestone member.—Above the Shaws sandstone member is the lower limestone of the Meadville limestone trio. It is a remarkably persistent limestone despite its thinness, being only 1.5 to 2 or 3 feet at the most. It was listed as the "Meadville lower limestone" by I. C. White[189]. He described it as "wedged in between the 'Sharpsville lower sandstone' and the 'Sharpsville upper sandstone' ". It has been traced in the past rather widely over the Crawford, Mercer and Venango Counties area and erroneously identified with the astonishingly similarly appearing limestones of the older Marvin Creek zone in the Kushequa shale of McKean County[190] [191] as well as with the far from similarly appearing "limestone" band (*Syringothyris* zone also Marvin Creek in age) of F. A. Randall which appears in Carll's note on the Warren, Pennsylvania section in his 1875 report[192]. Hodge was the first to describe the limestone in

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[188] **Idem.**, p. 89.

[189] **Idem.**, p. 87.

[190] C. A. Ashburner, Report on the geology of McKean County and its connection with that of Elk and Forest, Second Penna. Geol. Surv., Report R, p. 69, 1880.

[191] J. P. Lesley, Second Penna. Geol. Surv., Summary and Final Report, vol. 3, part 1, p. 1731, 1895.

[192] J. F. Carll, Report of progress in the Venango ounty district, (containing observations on the geology around Warren, by F. A. Randall,). Second Penna. Geol. Surv., Report I, p. 53, 1875.

Crawford County, though he did not name it[193].

This limestone is usually very hard and siliceous. It breaks with a glistening, almost glassy lustre and with conchoidal fracture. It is uniformly non-fossiliferous in all places where its presence is known. The statements which White makes (Crawford County Report[194]) about this limestone being represented by a "mass of broken shells" in Warren County and elsewhere were based on a misidentification.. The *West Mead limestone* is not present, as far as known, in Warren County, Pennsylvania. White was correlating the Marvin Creek limestone, which occurs below the Corry sandstone, with this upper limestone. The name West Mead, which is here proposed for the "Lower Meadville limestone" comes from the township by this name, Crawford County, Pennsylvania. The member is especially well developed in gullies, runs and ravines within this township.

Sharpsville sandstone member.—The medial member of the original Sharpsville formation was the "Sharpsville upper sandstone"[194]. This member is the most prominent of the several making up the Sharpsville suite, but is not more than 50 feet thick in the type area. Only a small percentage of the sandstone is quarryable. Most of the sequence is yellowish flags and shales, containing sporadic occurrences of locally thickened sandstone lenses. But the rock is soft, easily weathers and usually is found as a talus slope along streams between the Meadville limestones. This member which is here recognized as the *Sharpsville sandstone member* of the Meadville monothem, constitutes the main part of what White called the Sharpsville sandstone or "Sharpsville formation".

Fish bones, brachiopods, especially the inarticulates, and the pteropod Conularia are relatively abundant, especially in the Crawford County development of the member. The fauna has never been described, but during this study rather large and exceedingly interesting collections have been made, and should prove to be of correlative value in future work.

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[193] H. D. Rogers, Third annual report on the geological survey of the State of Pennsylvania. (J. T. Hodge's report on the operations of the Survey in the fifth district . . ., Strata of the northwestern part of the state, which lie below the Coal Measures,) pp. 109-114, Harrisburg, 1839.

[194] I. C. White, Report on the geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, pp. 85-87, 1881.

The eastward correlation of the Sharpsville sandstone has been a difficult problem because of its poor definition and seemingly depauperate fauna toward the east. The sandstone is present on the Allegany River near Tidioute, and has been tentatively traced to the vicinity of Ridgeway, Pennsylvania, where it is thought to be represented by a massive sandstone above the Berea horizon. (The Berea is apparently represented in an hiatus on the Ridgway meridian).

Byham limestone member.—At the base of the shale member which overlies the Sharpsville sandstone in several of the ravines south of Meadville, Pennsylvania, and especially in Buchanan's Ravine, north of Shaws School, (Buchanan Station) on the Meadville topographic sheet, there is a limestone similar in appearance to the West Mead limestone ("Lower Meadville limestone"). It is especially well developed south of Meadville in most of the ravines descending to French Creek from the east. From the Buchanan Ravine occurrence, about a mile and a half west north-west of Byham School (see topographic sheet), it is proposed that the "middle Meadville limestone" be known as the *Byham limestone.* The Byham limestone is very similar lithically and faunally to the West Mead limestone. Both limestones are characterized by iron-ball concretions, fish bones and a Syringothyrid fauna which is interspersed with inarticulate brachiopods. Both recall the physical appearance of the Marvin Creek limestones of the Knapp suite, below, though they are by no means faunally related.

The Byham limestone cannot be as widely traced as the upper and lower Meadville limestones. In the area immediately around Byham School, however, it is of considerably greater thickness (3-12 feet) and much used in the past for lime.

Harvest Home shale member.—For the "Meadville lower shales" of White[195] the name *Harvest Home shale* is proposed. This name is selected because of the excellent exposure of the member along Rock Creek, Greenwood Township, Crawford

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[195] Idem., p. 85.

County, Pennsylvania, especially at Peterson's Falls where the "Harvest Home Grove" is located. This picnic grove on the edge of the falls is widely known in Crawford County.

The appropriateness of this name has been questioned by one stratigrapher who read the monuscript. It would seem that an institution which has been established for thirty years in a community and known far beyond the county boundaries is amply established to warrant having its name selected for a stratigraphic member which is wonderfully well developed adjacent to it. Peterson's Falls are a part of the Harvest Home grove, the Peterson school is adjacent, and the whole is located on the Peterson farm. Unfortunately, the name Peterson is unavailable for a stratigraphic unit. It is advisable to have this specific outcrop for the type section. The name *Harvest Home* seems to be the best available name.

The Harvest Home shales are lithically similar to the upper shales of the Meadville group[196], presently to be described. Ash gray color, flaggy beds alternating with sandy shale and fine shale, characterize them. This member becomes more sandy toward the base. Thickness is rather constant throughout the territory bordering Conneaut Outlet, being from 45-50 feet. No fossils are known. None were found in rather detailed sectioning designed for their discovery. It is presumable that *Syringothyris* and *Conularia* as well as inarticulate brachiopods occur in the member because of the discovery of fragments of these forms in talus slopes presumably derived from the Harvest Home shale.

French Creek limestone member.—The "Meadville upper limestone" was described by White[197] in his Crawford County report. It is in many respects the most interesting of these several Meadville limestones. As has already been pointed out, this member, together with the sporadic middle limestone (Byham) is one of the most characteristic features of the lower Mississippian in northwestern Pennsylvania. The Marvin Creek limestone of the Kushequa shale is lithically similar. It is here proposed that the upper Meadville limestone be known by the more specific name of *French Creek* limestone.* It is so called from the outcrops of the member in ravines eroded by tributaries to French Creek, Crawford County, Pennsylvania. The type section for this member is the ravine at the "Glendale" Cemetery in the city of Meadville, Pennsylvania.

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[196] I. C. White's "Meadville group", sensu stricto, embraced only the lower Meadville shale, upper Meadville limestone and the upper Meadville shale. It might be suggested that these three units constitute the Meadville formational suite. So they would, but such differentiation here seems pointless, especially in as much as the name Meadville has already been used for the monothem, for which it seems advisable to restrict it.

[197] Idem., pp. 83, 84.

The French Creek limestone is usually about 1 foot thick, but is over 2 feet thick in ravines south of Meadville, on the east bank of French Creek. The French Creek member is about as widespread as the West Mead limestone. Both are of greatest stratigraphic value in this countryside.

The French Creek limestone is usually replete with fossils. The faunal list is a long one, but made up in the main of undescribed species. The predominant elements are inarticulate brachiopods and an abundance of fish bones. In fact fish bones and teeth are so common in places as truly to make it a fish bone conglomerate or glomerate. Two new species of *Spirifer,* at least two new *Syringothyris,* a new *Productus,* of the *P. ovatus* group and several pelecypods and gastropods, as well as many other forms, are in the collections at Cornell University.

*Note: The name "French Creek" is proposed at this point to supplant the name "Conneaut" used in earlier parts of this paper for the same member. The name "Conneaut" was fitting for the excellent development of the member in the gorge of Rock Creek at Custards, a tributary to the Conneaut Lake Outlet. The substitution is made at the request of G. H. Chadwick that Conneaut may be used as a group name in his forthcoming revision of the "Portage" and "Chemung." The name Conneaut is especially fitting for the unit to which he is applying it and "French Creek" is equally appropriate for the Mississippian limestone of this paper. Attention is called to the use of the supplanted term in the preceding "List of Strata Occurring in Northwestern Pennsylvania".

The name **Conneaut** is introduced to embrace the Girard and Chadakoin stages of the Upper Devonian in northwestern Pennsylvania, and also the underlying Cuba sandstone further east. The wording of G. H. Chadwick's manuscript in this matter is as follows: "To these pseudo-Chemung beds, from the base of the Dunkirk to the base of the Cuba sandstone, I am proposing to apply the substitute and distinctive name Canadaway group, and to those from the base of the Cuba sandstone to the base of the Wolf Creek (Panama) conglomerate, in which the fauna has been modified by loss of **Delthyris mesacostalis** and the accession of **Camarotoechia (?) duplicata**, the name **Conneaut group**".

At the base the French Creek limestone generally has a zone of iron-ball concretions, usually formed about fossil fragments. Ordinarily the limestone does not intergrade with the shale above or below.

This limestone is not known on the Allegany River at Tidioute as has been reported,[198] nor can it be traced far east of the Meadville area. Southward the member can be traced to the vicinity of Oil City and Franklin. At the latter it is carried below the surface by regional dip.

Custards shale member.—At the top of the Meadville monothem in Crawford County there is a shale member which overlies the French Creek limestone. This shale was mentioned by White[199] in his original discussion of the Meadville formation as the "Meadville upper shales." From the exposures of this shale member in the vicinity of Custards village on Conneaut Creek, Crawford County, Pennsylvania it is proposed that this member be known as the *Custards shale.* The best exposure is at Peterson's Falls on Rocky Creek, two miles west of Custards. It is also well exposed on Mill Run at Meadville, Pennsylvania and in many other places, the chief of which are listed by White[199] in his original discussion of the member.

A small, unstudied fossil fauna is present in the Custards shale. Fragments of Spirifer and Syringothyris and also Conularia are commonest. Its thickness in Crawford County is from 25 to 30 feet.

Summary of the Meadville monothem.—The Meadville monothem apparently represents a recurrence of conditions somewhat similar to those which had existed in western Pennsylvania during the Cussewago age. The similarity of environmental conditions indicated by the strata of the Cussewago and the Meadville sequences is striking. The Marvin Creek limestone and the Meadville limestones are markedly similar lithically. This similarity impresses one the more the strata are studied. It is small wonder that the earlier geologists with their predilections for long-distance correlation should have unhesitatingly correlated these beds.

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[198] I. C. White, Report on the geology of Erie and Crawford Counties. Allegany River section, Tidioute Bluff. Second Penna. Geol. Surv., Report Q4, pp. 71-72, 1881.

[199] Idem, p. 83.

This lithic similarity of the Meadville monothem and the Cussewago stage seems to the worker in the field as one more bit of suggestive proof of the Mississippian age of the Cussewago. The Conditions of Kushequa shale accumulation were virtually identical to those of the Meadville.

SHENANGO STAGE

SHENANGO MONOTHEM

I. C. White differentiated[200] the "Shenango group" above the "Meadville group" and below the Sharon (Pottsville) conglomerate in Crawford County, Pennsylvania. This group was to include his previously described[201] Shenango sandstone and the overlying shale which he termed the "Shenango shale" in his 1880 report[200] The Shenango group was early recognized by White and others as constituting the upper part of the Cuyahoga formation of Ohio. This Shenango group is here recognized as a monothem of the Crawford series (which might be with equal propriety called the "Cuyahoga series"). The reasons for this resurrection of the long abandoned Crawford bracket are discussed above.

It is impossible to correlate the Shenango monothem with either the Mauch Chunk and Pocono formations of eastern Pennsylvania or the formations of the same names in Ohio. Considerable field work is necessary before these relationships can be spoken of authoritatively. It is largely through the work of Ashburner[202] who was chief of the "long distance" correlators, that we have the current correlation of the Shenango group of western Pennsylvania with the Pocono of eastern Pennsylvania. Available field evidence at present does not substantiate this long range correlation. Nor is there more evidence for the correlation of the Mauch Chunk with the Shenango which Chance[203] proposed from his studies of Clinton County, Pennsylvania. At the present status of knowledge, chiefly characterized by its lacunae, of the nature of east-west relationships of the Mississipian strata in northern Pennsylvania, and with constantly increasing ground for doubt of all former correlations across Northern Pennsylvania as a result of the revelations of "Catskill" relationships [204,208] it is not practical to correlate the Shenango sandstone with any formation east of the Allegany River at present. It is presumable that further study along the southern range of the territory covered in this study will prove the Shenango continuous to at least the "Altoona angle".

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[200] Idem, pp. 77-82.

[201] Report of progress in 1878, the geology of Mercer County. Second Penna. Geol. Surv., Report Q3, pp. 60-61, 1880.

[202] C. A. Ashburner, The geology of McKean County and its connection with that of Cameron, Elk and Forest. Second Penna. Geol. Surv., Report R, p. 66, 1880.

[203] H. M. Chance, Geology of Clinton County, Part II, A special study of the Carboniferous and Devonian strata along the west branch of the Susquehanna River. Second Penna. Geol. Surv., Report G4, p. 113, etc. 1880.

Shenango sandstone.—(*Johnsonburg sandstone*). The Shenango sandstone is one of the great sandstones of western Pennsylvania. It has been traced all over the western counties and has been variously identified in former times as the "Sub-Olean conglomerate," "Sub-Garland conglomerate," "Upper Pocono sandstone," or simply as the "Ferriferous sandstone." It takes its name from the Shenango River in Crawford County. This is one of the most dependable stratigraphic horizons in western Pennsylvania. The outstanding characteristic is its coarse flat-pebble nature, and abundance of iron ball concretions and prevalent vein fillings of iron. The whole sandstone, is usually golden brown to dark brown in color, and sometimes reddish on weathered surfaces. The Shenango is about 45 feet thick in the western counties. It is cut out westward, and appreciably thickens eastward at the expense of the overlying Shenango shales as W. A. Verwiebe has pointed out.[209] To the south this sandstone and the overlying shale interval become predominantly sandy

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[204] G. H. Chadwick, The Chagrin formation of Ohio. Geol. Soc. Amer., Bull., vol. 36, pp. 455-464, 1925.

[205] **Idem**, Pocono problem, (abstract), Geol. Soc. Amer., Bull. vol. 43, p. 273, 1932.

[206] **Idem**, Red beds in eastern New York,, Science, n. s., vol. 77, pp. 86-87, 1933.

[206a.] **Idem**, Great Catskill delta. Pan American Geol., vol. 60, pp. 91-108; 189-205; 275-287; 348-360, 1933.

[207] G. A. Cooper, Stratigraphy of the Hamilton group of eastern New York. (abstract), Geol. Soc. Amer., Bull., vol. 44, pp. 200-201, 1933.

[208] Bradford Willard, "Catskill" sedimentation in Pennsylvania, Geol. Soc. Amer., Bull., vol. 44, pp. 495-516, 1933.

[209] Correlation of the Mississippian of Ohio and Pennsylvania. Am. Journ. Sci., vol. 43, p. 302, 1917.

and are known as the Burgoon formation.[143,210] There is no consensus as to the exact relationship of the Shenango sandstone to the Royalton and the Logan formations of Ohio, although various correlations have been suggested in literature.

The lithology of the Shenango is somewhat similar to that of the Cussewago sandstone, though more tightly cemented. The contact with the underlying beds is sharp in all the sections examined, but always disconformable. This is true also of the contact with the overlying shales. The Shenango sandstone is cut out of the Allegany River section a short distance northeast of Tidioute, Pennsylvania and is not present at Warren. This is clearly shown by C. Butts in his Allegany River section of 1910. From Meadville to Oil City and subsurficially further southward the Shenango is of rather consistent lithology and thickness. Toward the southeast and eastward from the Tionesta meridian the Shenango sandstone thickens, as previously explained, at the expense of the overlying shales. This feature is rather well shown by a series of sections and well logs across Venango, Forest, Elk and Cameron Counties to Johnsonburg, Pennsylvania. In the face of the second tier of the lower cuttings of the Yingling-Martin shale quarry at the latter place a thick flaggy to massive yellow sandstone charged with plant material (see section given previously) is believed to be on the horizon of the Shenango sandstone. This correlation is tentative. Until it can be carefully checked it is suggested that the massive member at Johnsonburg be known as the *Johnsonburg sandstone*. The available published sections rather strongly indicate the coevality of the Johnsonburg with the Shenango on the Allegany River.

In the areas west of the Allegany River the Shenango usually carries a large and plentiful fauna showing marked affinity to the fauna of Meadville monothem below. *Athyris aff. lamellosa, Spirifer sp., Orthothetes* and *Schuchertella sp.* as well as *Syringothyris aff. carteri* and many pelecypods and crinoidal fragments are the chief components. Eastward fish bones and plant frag-

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[210] See: Charles Butts, Pre-Pennsylvania stratigraphy of northwestern Pennsylvania. Penna. Topo. and Geol. Surv., Report for 1906-1908, pp. 190-204, 1908.

ments are of increasing abundance.

Hempfield shale member.—Above the Shenango sandstone in Crawford County are from 45 to 60 feet of bluish gray to olive green, brown-weathering shale and thin sandstone flags. The latter element is progressively more prominent eastward. I. C. White[211] described this member in his Crawford County report as the "Shenango shale". Inasmuch as the name Shenango is being restricted to the sandstone member of the monothem it is proposed that the "Shenango shale" of old be henceforth known as the *Hempfield shale member* of the Shenango monothem. This member is well developed in Crawford County as pointed out by I. C. White, and also nicely shown in and about the city of Greenville, Hempfield Township, Mercer County, Pennsylvania.

As I. C. White pointed out, the Hempfield shale carries near its base a layer of iron-ball concretions. These are a good recognition character in most sections. Fossils are not common in the shale. A few poor specimens seem to indicate a close faunal affinity between the Hempfield shale and the Shenango sandstone, thus strengthening the monothemic bond.

The Hempfield shale was correlated by the geologists of the Second Pennsylvania Geological Survey with the Mauch Chunk shale of north central Pennsylvania. It would seem that this correlation was and is unwarranted for lack of evidence. It is within reason, though yet to be proven that the Hempfield and the so-called Mauch Chunk of western Pennsylvania (especially environs of Pittsburgh) are correlates. The afore-going statement would imply, as the absence of information would seem to justify, inadequate information in the past and present about the westward development of the true Mauch Chunk shale. The purported Mauch Chunk of western Pennsylvania overlies the Greenbriar limestone which is in turn above the Burgoon formation. The relation of the Hempfield to these strata is yet to be shown. At Johnsonburg, and elsewhere on the Clarion River there is found a narrow band of red shale, usually not over 10 feet thick in the area about Johnsonburg, which overlies the Johnsonburg sandstone by approximately 60 feet. This intervening sequence, composed of olivaceous flags and shale, is tentatively correlated with the Hempfield shale. The red beds above have been termed by the geologists of the Second Survey as Mauch Chunk. These reds thicken rapidly toward the south and apparently southwest. They may be the correlates of the "Mauch Chunk" of the Pittsburgh area. Their connection to the east is likewise indefinite at present.

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[211] The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, p. 78, 1881.

*Greenbriar series**

Above the Shenango monothem in western Pennsylvania comes a wedge of limestone from the south which faunal evidence would indicate overlies the Hempfield shale and is represented in the hiatus between the Shenango monothem and the Pottsville of Crawford County. Absent on the upper Allegany River and also apparently absent on the Clarion River, beneath the so-called Mauch Chunk shale. This wedge constitutes the "Green briar series" which is well exposed and best developed in the vicinity of Pittsburgh. This series comprises the siliceous *Loyalhanna limestone member* at the base, followed by a red shale sequence which has been called "Mauch Chunk". These red beds are overlain by the *Greenbriar limestone member* which is in turn overlain by another red shale member which has been called the *Upper Mauch Chunk* shale. The red elements of this series seem to extend further north than the limestones. The red shale overlying the purported Hempfield shale in the vicinity of Johnsonburg and Ridgway on the Clarion River may be continuous with one or both of these red shales of the Greenbriar series in southwestern Pennsylvania. It seems probable, at any rate that the Greenbriar series entirely overlies th Shenango monothem. For the red shale member (or composite member) on the Clarion River, which in the past has been called the Mauch Chunk, the name *Cameron red shale member* is proposed. This member can be studied very well from the well sections and surface exposures in Cameron County, Pennsylvania. The series of well sections published by Ashburner and Shaeffer[212] running from Bradford, McKean County

*No brief is held for the classification of the Greenbriar sequence here given. This unit lies outside the area of the present investigation, and its relation to the current problem is presented with apriority.

[212] C. A. Ashburner, The geology of McKean County and its connection with that of Cameron, Elk and Forest Counties, Second Penna. Geol. Surv., Report R, Plate 11, 1880.

southward through Wilcox and Johnsonburg show the rapid thickening of the member toward the south. Good exposures occur at Ridgway, Emporium and Franklin, Pennsylvania. The determination of the relationship of the Cameron shale to the Mauch Chunk of Carbon County and the Greenbriar red shales of southwestern Pennsylvania is a fascinating problem in correlation yet to be undertaken.

CORRELATION

The correlation of the respective stratigraphic members found in northwestern Pennsylvania with those described from adjacent areas has been a perplexing problem which it has not been possible in the available time comprehensively to solve. At first glance it might seem that correlation in this region would be especially facilitated by the great number of published records of oil wells. Of course these records are an invaluable adjunct, but their inaccuracies are manifold. In general the average of many sections in a specific area proves dependable. Modern workers are indeed grateful for the thousand odd sections of the older wells preserved in the reports of the Second Pennsylvania Geological Survey. From these sections and supplimentary ones it has been possible to work out with moderate assurance the relation of the surface and subsurface strata of the upper Chautauquan and Venangoan as well as the Lower Mississippian of the northwestern counties of Pennsylvania, the mass of these facts being hereinbefore incorporated. In this aforegoing exposition the members occurring typically at the surface in southwestern New York have been included. The New York and Pennsylvania State line is a less forbidding stratigraphic barrier than that between the latter state and Ohio.

The correlation of the formations of northwestern Pennsylvania and the supposed equivalents in Ohio is at best somewhat intuitive. The difficulty lies in the paucity of outcrops in both states adjacent to the boundary. This phase of the problem is subsequently taken up. The correlation of the surface outcrops in western Pennsylvania with the oil sands to the south is a matter of some import which has been previously touched upon. A very detailed and scholarly report on this problem has been prepared by G. H. Chadwick (1930) for the Topographic and

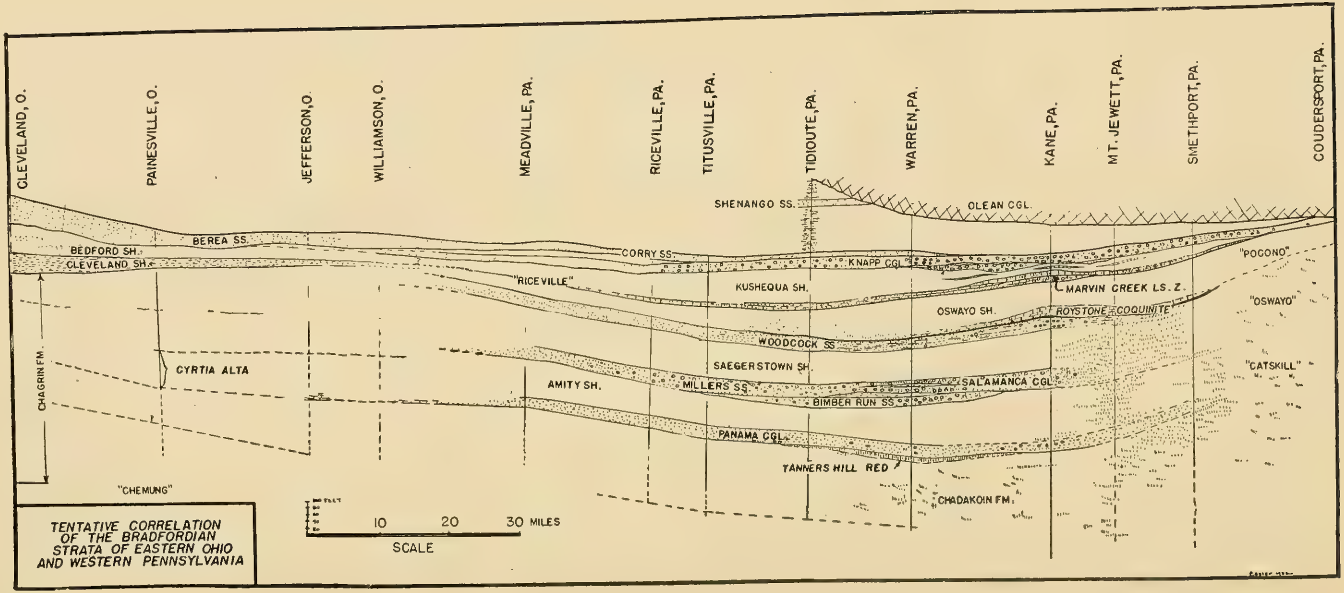
CLEVELAND, O.
PAINESVILLE, O.
JEFFERSON, O.
WILLIAMSON, O.
MEADVILLE, PA.
RICEVILLE, PA.
TITUSVILLE, PA.
TIDIOUTE, PA.
WARREN, PA.
KANE, PA.
MT. JEWETT, PA.
SMETHPORT, PA.
COUDERSPORT, PA.
SHENANGO SS.
OLEAN CGL.
BEREA SS.
BEDFORD SH.
CLEVELAND SH.
CORRY SS.
KNAPP CGL.
"POCONO"
"RICEVILLE"
KUSHEQUA SH.
MARVIN CREEK LS. Z.
"OSWAYO"
OSWAYO SH.
ROYSTONE COQUINITE
WOODCOCK SS.
CHAGRIN FM.
CYRTIA ALTA
SAEGERSTOWN SH.
"CATSKILL"
AMITY SH.
MILLERS SS.
SALAMANCA CGL.
BIMBER RUN SS.
PANAMA CGL.
TANNERS HILL RED
"CHEMUNG"
CHADAKOIN FM.
10
20
30 MILES
SCALE
TENTATIVE CORRELATION OF THE BRADFORDIAN STRATA OF EASTERN OHIO AND WESTERN PENNSYLVANIA

Fig. 10.—Composite section across Pennsylvania, from eastern McKean County to near the City of Cleveland, Ohio.

Geologic Survey of Pennsylvania and is now on file in Harrisburg. Mr. Chadwick has very generously permitted the leisurely examination of this report. In the main his correlations are in agreement with those of this report. Points of difference have been brought out in the previous text.

The eastward and southeastward correlation of the strata in northwestern Pennsylvania, especially of the Mississippian members, presents a temporarily intangible problem. This is taken up under the head of the Pocono and Mauch Chunk correlation problem below.

THE CORRELATION PROBLEMS INVOLVED IN THE DETERMINATION OF THE AGE OF THE POCONO AND MAUCH CHUNK FORMATIONS OF PENNSYLVANIA

The Pocono and Mauch Chunk formations of eastern, southern and southwestern Pennsylvania are a controversial unit in the geologic column. Their age for many years has been universally conceded to be early Mississippian. From commonly reported gradation between the lower Pocono sandstone and the overlying red Mauch Chunk shale it seems probable that they constitute an approximately continuous record. They are almost universally recorded as overlying red beds of Devonian age belonging to the Catskill facies. The correlation problem centers in eastern and south central Pennsylvania where are exposed lithically and sequentially similar strata which were deposited on opposite sides of the shallow head of the relict Appalachian trough. They are separated by closely folded strata from which a large part of the purported coeval beds are removed by erosion.

The question has arisen whether these two sequences, the one in the southern foothills of the Pocono Mountains and the other, in general, in the eastern Appalachians, are coetaneous deposits;

Note: In Figure 10, opposite, the sections between Riceville and Warren, Pennsylvania show the Corry sandstone directly overlying the "Knapp conglomerate". Since the figure was engraved the relationships outlined in the text of the paper have been discovered; the Hayfield shale and Tidioute shale of the Hayfield monothem intervene between the Corry and the Knapp in these sections, and at least the Tidioute (doubtfully the Hayfield shale) intervenes virtually as far east as the Corry sandstone occurs along the line of this section. Likewise, the three-fold nature of the Berea sandstone in Ohio is not clearly shown in this diagram. This defect is also remedied in the text.

if so, how to coordinate the definite Mississippian age[213] of the seaward sequence with the postulated[205],[206],[206a] Devonian age of the sequence in the foothills of the Pocono Mountains.

The "Pocono" sandstone of central Pennsylvania carries Mississippian plants according to Dr. David White; to the south Mississippian marine faunas are intercalated with the typical sands. On this basis the "Pocono" has been correlated with Mississippian strata in southwestern and western Pennsylvania and Ohio.[214] As has been previously shown, this correlation cannot be judged at the present state of our paleontologic knowledge. The Mississippian age determination must stand, however.

The Pocono sandstone of the Pocono mountain area has always been considered to be the same formation as the "Pocono" further south. But G. H. Chadwick[205] has observed that the New York and Pennsylvania Upper Devonian strata as traced eastward take on a lithology that is strikingly similar to the Pocono sandstone. That facies has been termed the "Pocono" facies in this report, for want of a bettter name. It seems probable that no one has ever attempted to trace the Pocono from the Pocono Mountains area westward to substantiate this contention. The literature dealing with the Pocono of eastern and northeastern Pennsylvania is somewhat complex and contradictory, especially the text and figures of the same reports. It is unlikely that anyone could present an accurate explanation of the relationship of the Pocono to the Catskill from these published reports alone. It is interesting to note that I. C. White was aware that none of his true Pocono is present in the Pocono Mountain escarpment, even though he mapped it as present at the horizon of the somewhat similar Cherry Ridge conglomerate several hundred feet down in the Catskill and then explained away his mistake as an aid to the layman in appreciating the plateau nature of the region. The Pocono sandstone, of common usage, occurs above these Devonian strata many miles back from the Pocono front, and the Pocono mountains proper. This may account for a part of the opposing opinions about the Pocono of northeastern Pennsylvania. Whether the Pocono sandstone which caps the hills west of the mountain area from which it takes its name but in which it does not occur is the same as the "Pocono" at East Mauch Chunk is an open question for which there is certainly as much positive as negative information available at present. In the type area, as elsewhere, the Pocono sandstone is disconformable with the underlying red "Catskill" shale. The upper Pocono intergrades with an overlying red shale. The "Pocono" on the Lehigh River, and in virtually every section where sufficiently exposed also intergrades with an overlying red shale, the Mauch Chunk. This latter carries Mississippian floras in the anthracite coal area and faunas of the same age further south. Beds of identical appearance in southwestern Pennsylvania, on the northwest side of the embayment are intercalated between the Mississippian Greenbriar limestones. It would seem that the Mauch Chunk shale is Mississippian, and is not directly related to the Upper Devonian facies development.

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[213] David White, The age of the Pocono. Am. Journ. Sci., vol. 27, pp. 265-273, 1934.

[214] D. B. Reger, Pocono stratigraphy in the Broadtop basin of Pennsylvania. Geol. Soc. Amer., Bull. vol. 38, pp. 397-410, 1927, correlates the Pocono with the sequence from Berea through Burgoon. This is an echo of the correlations made by the geologists of the Second Pennsylvania Survey.

By way of summary of the controversy the nomenclatorial nature of the problem rather than its stratigraphic aspect must be emphasized. There is no argument about the existence of both a Devonian "Pocono"-like magnafacies in the Catskill delta deposits to the east of the typical red magnafacies; nor will any deny, who are familiar with the strata, that there are present over a large area of Pennsylvania beds of "Pocono"-like lithology which overlie Devonian beds and do not grade laterally into the magnafacies which characterize the Devonian delta beds of the same general territory. These latter beds are the ones which carry Mississippian faunas and floras and the ones to which the name "Pocono" is linked in common and long accepted usage. The problem now arises whether this usage despite its ubiquity in print is tenable on the grounds of strict priority of usage and particularly of specific geographic designation.

When I. C. White proposed the name Pocono for a sequence of strata he unquestionably intended the name for the strata ever since called by that name: i.e., Lower Mississippian strata. His intention was excellent, but in his choice of a type section of exposure, misguided as he was at the time by the current concept of parallelism of strata and ignorance of the facies pattern of the Catskill delta beds, he selected the sandstone of the Poconos as the type and therefrom chose the name. These beds in the Poconos he later recognized as laterally gradational into Devonian strata and underlying the strata which he had endeavored to name. He recognized, as must all workers in that area that the type Pocono is Devonian. The name "Pocono" ought, therefore, on the grounds of strict priority to be used for this Upper Devonian sequence of the Pocono mountains. Because of the transcendency of the contemporaneity planes by this Pocono type of lithology in the Upper Devonian delta deposits it might clarify matters to use the term Pocono in the sense herein tentatively employed, that is, as a magnafacies term.

Some new or acceptable name should be used for the sequence of Mississippian age for which the name Pocono has long been employed or else by common consent of stratigraphers the legality of "Pocono" as basal Mississippian should be established. The grounds for the latter procedure would be largely convenience and a testimony of the modern appreciation of the good intention of I. C. White. The problem is, briefly, nomenclatorial and not stratigraphic.

It is unfortunate that this highly speculative and justifiably contested association of the Pocono and Mauch Chunk with the encroachment of the Catskill delta was so prematurely suggested.

CORRELATION OF THE UPPER CHAUTAUQUAN, VENANGOAN AND LOWER MISSISSIPPIAN IN EASTERN OHIO AND NORTHWESTERN PENNSYLVANIA.

The correlation of Upper Devonian and Lower Mississippian strata of western Pennsylvania and eastern Ohio has been a serious stratigraphic problem ever since the successions in the two areas have been known. The Chagrin shale (Erie shale) of Ohio embraces in a single facies, according to some workers, part of the Chemung formation, all of the Chadakoin as well as the Conewango series of New York and Pennsylvania. If this concept is wholly true, then all of these eastwardly well differentiated categories and their respective components are uninteruptedly and practically indistinguishably represented by one homogeneous terrane in Ohio. However, it is proven by faunal and lithic tracing that this concept is far from field actualities.

In eastern Ohio the Conewango sandstones and shales are still clearly differentiated in the Chagrin terrane. The disconformities are less obvious in the changed facies; some may be omitted, but the faunal zones are as delimited as they are in more eastern facies provinces. Field studies only further substantiate this fact which is well brought out in Prosser's Devonian and Mississippian sections in northeastern Ohio (Ohio Geol. Surv., Bull. 15, 1912). Chadwick's work[204] also illustrates the presence in the Chagrin terrane of members typically developed in Pennsylvania.

In the summer of 1932 during a reconnaissance trip into Ohio most of Prosser's sections were studied. It was clearly demonstrated that despite the apparent lithic homogeneity of the Chagrin terrane that the faunal break at the bottom of the Venango stage is as clearly marked in Ohio as in western Pennsylvania or New York.

This is illustrated by a section in the upper Chagrin shales exposed on Mill Creek, northeast of Jefferson, Ohio. This is a locality described by H. P. Cushing[225] and C. S. Prosser and is famous due to the disconcerting presence of *Syringothyris*. At the railroad bridge across the creek a sequence of bluish shales and buff-weathering sandstones carries an abundant fauna composed chiefly of *Leiorhynchus**. This genus is especially characteristic of the particular parvafacies of the Chagrin there exposed. One fourth of a mile above the bridge, and approximately fifty feet above the *Leiorhynchus* beds in shales and sandstones lithically similar are several thin limy layers in the midst of somewhat sandier beds. In the limy layers is found the typical fauna of the Panama-LeBoeuf conglomerate of northwestern Pennsylvania; this fauna is chiefly characterized by certain species of the pelecypod, *Ptychopteria*. Associated with the Panama fauna are many *Syringothyris chemungensis*. Above the horizon of the Panama conglomerate there is no recurrence of representatives of *Syringothyris* on Mill Creek, or elsewhere so far as known in the entire Chagrin of Ohio. Near the middle of the intervening shale sequence, between the *Syringothyris* occurrence and the top of the Chagrin, a somewhat sandier member carries the unmistakable fauna of the Millers (Pope

*See Chadwick, 1934, bibliography.

Hollow member of the Salamanca suite) sandstone. This Millers fauna is composed of a characteristic mutant of *Spirifer disjunctus,* representatives of *Pararca* and several characteristic species of *Ptychopteria,* including *P. beecheri.*

The Chagrin in eastern Ohio is terminated by the Riceville-Oswayo shale (as delimited in this report from the Knapp shale). No evidence is known which would indicate that the Chagrin extends higher in the column than this member at the top of the Conewango series.

There now remains the resolution of the strata of the Cussewago stage of Pennsylvania into the Ohio rock column. Due to the absence of any sections in which the supra-Chagrin strata of Ohio and the supra-Conewango strata of Pennsylvania occur very close to each other geographically the problem becomes somewhat difficult.

In Ohio the Cleveland shale and the Bedford shale with its included sandstone lenses occur between the Chagrin formation and the Berea sandstone. In Pennsylvania the Kushequa shale and the Knapp suite of conglomerates (Cussewago sandstone sequence) of the Cussewago stage intervene between the Conewango strata and the Berea sandstone. This parallelism is suggestive, apparently too suggestive for some geologists.

The question arises as to the relationship of the Cleveland shale to the Chagrin formation of Ohio. This arises from the search for significant breaks in the sedimentary record which may have reflections in both sections.

Several excellent geologists among whom are G. H. Chadwick[215] and H. P. Cushing[216] feel convinced of the disconformable contact between the Cleveland and the Chagrin. They maintain that the intergradations of the two formations which have been noted are erroneous interpretations, and that the Chagrin was subjected to considerable erosion prior to Cleveland deposition. The difficulty with this concept lies in the untrustworthy criteria used to determine the age of the Chagrin beds in contact with the presumed overlap of the Cleveland. Chadwick[215] reports that at one place the uppermost Chagrin beneath the summit unconformity is the Millers sandstone, "characterized by its abundant fauna," and again it is the Woodcock, similarly characterized. In reality the fauna of neither in Ohio has been sufficiently well known to this time to warrant such stratigraphic identifications.

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[215] G. H. Chadwick, The Chagrin formation of Ohio, Geol. Soc. Amer., Bull., vol. 36, p. 461, 1925.

[216] Geology and mineral resources of the Cleveland district, Ohio. U. S. Geol. Surv., Bull. 818, pp. 35-38, 1931.

Another school of geologists, including C. S. Prosser[217] and E. M. Kindle[218] are inclined to the idea that the Chagrin shale grades westward into the Cleveland shale facies. This gradational relationship is rather well shown by Prosser's Big Creek section,[217] at East Brooklyn, Ohio, where he indicates that a progressively greater amount of Chagrin shale becomes "Cleveland" when traced westward.

This evidence would tend to suggest that the black shale facies is progressively assumed in this part of Ohio in a reverse direction for a normal Upper Devonian facies. The common condition for this area of off-shore deposition in front of the encroaching Upper Devonian delta or deltas has been a gradual westward migration of the eastern facies. The Cleveland, if gradational below, apparently encroaches *eastward* as repeated sections in eastern Ohio seem to indicate.

On the basis of geographic conditions which are rather well established as existant in the area west of Cleveland during the early Mississippian period when the crest of the Cincinnati dome was emergent from the sea[219] it does not require a great amount of imagination to picture this uplift as having been in progress throughout Chagrin time. Such an uplift would have tended to narrow the eastern Chagrin seaway and might even have gone so far, had it been emergent or nearly so, as to have established an encroaching facies from the west, or at any rate effectively precluded westward encroachment of eastern facies.

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[217] C. S. Prosser, The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., Fourth Series, Bull. 15, pp. 27-28, etc. 1912.

[218] E. M. Kindle, The stratigraphic relations of the Devonian shales of Ohio. Amer. Journ. Sci. (4), vol. 34, p. 200, 1912.

[219] For varying opinion of early Mississippian conditions in Ohio and Pennsylvania see: J. E. Hyde, The ripples of the Bedford and Berea formations of central and southern Ohio, with notes on the paleogeography of that epoch. Journ. Geol., vol. 19, pp. 257-269, 1911.

This might be called stemming the tide of Catskill encroachment and turning the western facies back on themselves.

To put the same view in another manner, toward the end of the Devonian period the gradient from the Catskill plain to the marine environment in western Pennsylvania and Ohio was decreased and the previously relatively rapid westward migration of eastern facies concomitant with continuous eastern uplift virtually ceased. Whereupon either eastern subsidence or western uplift or both created the temporary condition of an eastward encroaching sea, so that sediments of a type formerly occurring in a more western environment now are deposited above facies of an eastern province. This would explain the Chagrin "wedge" between the Huron shale on the bottom and the Cleveland shale above. This is well shown by Kindle's diagram,[220] figure 3. Of course, this figure is somewhat erroneous in the light of Prosser's findings[221] of 1913 relative to the relationship of the Huron and Cleveland formations. Prosser concluded that the Huron shale is a western facies of the Chagrin. The present contention is that the Huron shale, which represents a normal western facies of Devonian deposition, was deposited prior to any effectual disruption of geographic conditions due to uplift on the Cincinnati arch in the Ohio area. The Cleveland shale, on the other hand, is a representative the same magnafacies, deposited during the progressive uplift of the arch, and is therefore a "reverted" parvafacies of the same magnafacies as the Huron. The sections which Prosser shows to indicate that the Huron shale underlies the Cleveland and is the western gradational facies of the Chagrin are taken from the geographic points near the tip of what is here spoken of as the

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[220] E. M. Kindle, The unconformity at the base of the Chattanooga shale of Kentucky. Am. Journ. Sci., (4), vol. 33, pp. 120-136, 1912, and The Stratigraphic relations of the Devonian shales of northern Ohio. Am. Journ. Sci., (4), vol. 34, pp. 187-213, 1912. Kindle's concept of a chagrin wedge is a true picture, of course, on the provision that E. O. Ulrich's rejoining opinion that the Huron shale overlies the Chagrin is incorrect. (The Chattanoogan series with special reference to the Ohio shale problem, Am. Journ. Sci., (4), vol. 34, pp. 157-183, 1912.

[221] C. S. Prosser, The Huron and Cleveland shales of northern Ohio. Journ. Geol., vol. 21, pp. 323-362, 1913.

"Chagrin wedge.."[222]

It is fully appreciated that to some stratigraphers anything so striking as the reversal of the direction of facies encroachment which is here suggested would be the structural basis for that much sought break in the geologic time scale between the Devonian and the Mississippian. However, this change in direction of encroachment, as envisaged at present, actually began about the middle of Chagrin time. Were the Mississippian to be considered as beginning at this point it would mean placing the systemic boundary downward near the point which J. S. Newberry indicated[223] might be better. It would mean placing the boundary at approximately the break between the Chadakoin and the Chemung. Evidence to support such a systemic boundary is certainly not present in the neritic zone of western Pennsylvania and New York. However, there does seem to be a substantial lithic and faunal basis, as previously reviewed, for drawing the boundary at the break between the Cleveland and the Chagrin.

As yet neither acceptance nor rejection of either concept of the Cleveland - Chagrin relationship is in order. In the light of the known facts the "reversal of facies" interpretation or some other along the same lines seems to be most satisfactory. Such a relationship would preclude the possibility of correlation of the Cleveland shale *en masse* with any specific Venango or Riceville development of Pennsylvania. According to this interpretation it would have been deposited synchronously, and thus be correlative with practically the whole Conewango series.

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[222] Bradford Willard writes, (letter, July 1933), in regard to the "eastern encroachment of the Cleveland shale" in the following rationalizing manner: "Supposing that Appalachia were considerably reduced in later Devonian time, the amount of clastic sediment supplied the seaway to the west would be relatively small. If so, an eastern encroachment of the pelagic upon or at the expense of the neritic might be assumed."

[223] J. S. Newberry, Review of the geologic structure of Ohio. Ohio Geol. Surv., Report III, p. 18, 1878; The Paleozoic fishes of North America. U. S. Geol. Surv., Mon. 16, p. 77, 1889; and Circles of sedimentary deposition in American sedimentary rocks. Am. Assoc. Adv. Sci., Proc., vol. 22, part 2, p. 192, 1874.

The fish and conodont fauna of the Cleveland shale, as was pointed out by E. M. Kindle[224] is essentially Devonian. It is relevant, however, that knowledge of fossil fishes is hardly sufficiently far advanced at even the present time to warrant any definite pronouncement on them alone even under normal conditions. It is necessary to bear in mind in discussing the Cleveland shale that in old faunal lists Newberry was confusing the true Cleveland shale of northern Ohio with the Mississippian Sunbury shale of southern Ohio. Thus many Mississippian species were recorded from the Cleveland shale which do not occur therein. C. S. Prosser has discussed this confusion[225]. Furthermore, in all likelihood the purported occurrence of *Syringothyris* in the true Cleveland shale of Ohio as reported by Newberry in the Geology of Ohio, is presumably erroneous; this despite the futile[226] attempt of H. P. Cushing[227] to prove this occurrence must be true by attempting to make Newberry personally responsible for the discovery. It was in conjunction with the attempt to reinstate *Syringothyris* in the Cleveland, where so far as is known at present it does not occur, that Cushing made known the existence of Syringothyris in the Chagrin at Jefferson, Ohio. The Chagrin Syringothyrid is not in any respect to be mistaken for a Mississippian form, nor does it belong within the same category as the Mississippian forms. The purported Cleveland Syringothyrids were supposedly of the true Mississippian type.

The Cleveland shale does not contain, so far as known at present, a single invertebrate fossil whose presence would unquestionably indicate a Mississippian age. Yet, it would be premature to pass judgment, for at present very little is known about the Mississippian black shale fossils. The facies aspects seem to indicate Devonic age.

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[224] The stratigraphic relations of the Devonian shales of northern Ohio. Am. Journ. Sci., (4), vol. 34, p. 200, 1912.

[225] The Sunbury shale of Ohio. Journ. Geol., vol. 10, pp. 262-272, 1910.

[226] Shown by Prosser's quotation of Newberry's actual words that Newberry did not specifically say that he **personally** collected the specimens of **Syringothyris** from the Cleveland shale. (Ohio Geol. Surv., Bull. 15, p. 21, 1912.)

[227] Age of the Cleveland shale of Ohio, Am. Journ. Sci., (4), vol. 33, pp. 581-584, 1912.

The faunal aspects and consequent age of the Cleveland shale have been dwelt upon at this length to make more clear the marked faunal change as well as important hiatus that occurs at its top. At the top of the Cleveland shale the relationship is somewhat similar to the basal relationship between the Cleveland and the Chagrin. Prosser has offered evidence of both conformable and disconformable contact of the Cleveland and Bedford. Throughout the larger part of Ohio the contact is seemingly conformable, but a marked lithic change is universally evident with the beginning of Bedford deposition. It seems probable from several sections where the Cleveland-Bedford contact has been examined that the apparent conformability is really due to a reworking of the black Cleveland mud in the lower Bedford. This is the conclusion at which Cushing also arrived after his very careful studies of the Cleveland in central and northern Ohio[228].

The consensus of the informed seems to indicate at least a slight disconformity at the base of the Bedford shale. This debated unconformity, which in places is angularly developed, is perfectly indicated by a marked faunal change from the Cleveland to the Bedford. Here there is no suggestion of a truly gradational contact. Faunally their contact is a fine example of a lower, Devonian facies-fauna in contact with an upper, presumably Mississippian (see faunal evidence below) faunal assemblage. The two faunas apparently have nothing in common with each other.

The Bedford shale clearly illustrates the development of a new facies province in Ohio. It might be interpreted as the seaward expression of initiatory deposition derived from a newly risen land mass, possibly "Cincinnatia," or the emergent crest of the Cincinnati arch. The Bedford shale seems to have been deposited under conditions somewhat remindful of the off-shore beds of the Catskill sediments in eastern New York and Pennsylvania. Sandstone lentils, fissile shales and a tendency to assume red coloration are all highly reminiscent. How far east the true Bedford shale was deposited is a mooted question. There is some evidence in scattered sections to indicate that the Bed-

[228] H. P. Cushing, Geology and mineral resources of the Cleveland district Ohio. U. S. Geol. Surv., Bull. 818, pp. 40-43, 1931.

ford lens extended east to the westwardly thinned edge of the western facies of the Kushequa shale of Pennsylvania. This actual or approximate confluence of the two occurred along the Meadville, Pennsylvania axis, or between there and the state line. This is suggested by figure 11 below. In both the Bedford and the Kushequa shales the fissility increases toward Meadville, the thickness diminishes, and the coarse sandstone characterizing the nearer-shore expressions of each virtually disappears. The problem of precise tracing is hampered by the fact that seemingly in Kushequa-Bedford time there was a shallow area in the sea-bottom, a shoal, so to speak, in the general meridian of Meadville, Pa. Perhaps during the deposition of the succeeding Knapp conglomerate suite ("Cussewago sandstone") much of the earlier Cussewago shales (Kushequa-Bedford) were scoured away so that the thickness of Kushequa on this crucial meridian is not over 25 feet at the most.

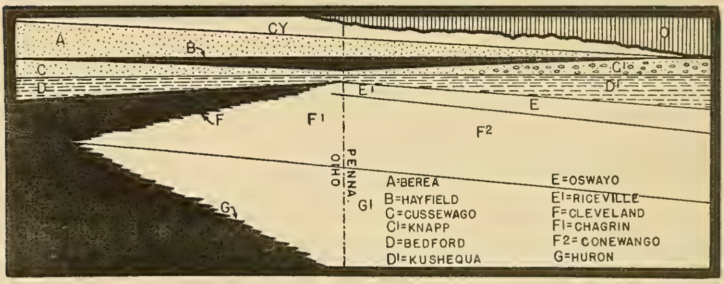

Fig. 11.—Diagrammatic representation of the present concept of the relationship of the basal Mississippian strata of Ohio and Pennsylvania to each other, and to the Devonian.

E. D. Ulrich[229] has suggested that there was a land mass in the general vicinity of the Ohio-Pennsylvania line in Upper Devonian-Lower Mississippian time. There is now present no evidence to substantiate such a conclusion, at least there is no stratigraphic expression of a land mass. The Cussewago sandstone presumably was deposited along an uneven east-west shoreline, which perhaps did extend southward on the Meadville meridian as a peninsula at this time. That the Bedford formation was derived even in part from a true land mass along the inter-state line seems lithologically impossible. W. A. Verwiebe also indicated the impossibility of an interstate land mass as a source of the Bedford. However, it must be remembered that Verwiebe[230] was correlating the Bedford formation with the Venango oil sand group of Pennsylvania.

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[229] The Chattanoogan series with special reference to the Ohio shale problem. Am. Journ. Sci., (4), vol. 34, pp. 157-183, 1912.

The Bedford shale and sandstone assume a finer grain toward the east, rather than coarser as the existence of an emerged land mass along the state line would seem to require. It is also interesting that the Knapp shales (Kushequa) assume a finer grain grain toward the west. This would seem to be a double argument against the barrier which Ulrich suggests.

As mentioned above, it is impossible to trace the Bedford formation into Pennsylvania and likewise impossible to trace the Knapp monothem into Ohio by surface exposures. The difficulty is not so much the moderately disconcerting paucity of outcrops as the concomitant change of facies in each formation toward the state line, as indicated in paragraphs above. That each formation when traced toward the typical area of the other gradually takes on a similar lithic facies is certainly suggestive of coevality. The eastern facies of the Bedford and the western facies of the Kushequa are virtually barren of fossils. The finer sediments, the paucity of fossils which are characteristic of either, and the thinning of the beds would perhaps point to a basin, rather than a barrier along the meridian of the state line. A basin may be as formidable a barrier against migration of a faunal assemblage as an isthmus, peninsula or shoal.

It is clear that, whether contemporaneous or not, there were in Bedford and Knapp time two locales of sedimentation and life, one in Ohio and the other in Pennsylvania, which paralleled each other not only in physical conditions, but in life development as well. The faunas, although they are identical in only few details, do show a striking parallelism which is suggestive of subspecific variation due to geographic isolation of organisms of common lineages.

[230] Correlation of the Devonian shales of Ohio and Pennsylvania. Am. Journ. Sci., vol. 44, p. 35, 1917.

It would be premature to lay too much stress on this principle, because of the largely undescribed nature of the two faunas. In the faunal lists below an attempt is made to assemble a complete catalogue of the Bedford fossils which have been described or indicated in literature. It would be a most opportune contribution should someone monograph the Bedford fauna in the near future. G. H. Girty's lists[231] constitute our chief knowledge of the Bedford fauna. Unfortunately, his long-promised monograph of the fauna is yet to appear. The Knapp fauna is even more imperfectly known by the public. However, collections are made and partially studied for a monographic treatment of this fauna. In the column of Knapp species in the lists below some anticipatory conclusions are suggested. Proof will be forthcoming in the near future.

It would appear at present, as explained above, that the Bedford shale of Ohio and the Kushequa shale of the Knapp monothem in northwestern Pennsylvania are contemporaneous and possibly at least partially laterally continuous deposits. The establishment of their coevality is largely dependant upon faunal evidence; the proof of their lateral continuity is a matter yet to be proven by field tracing. This latter accomplishment may prove impossible. To date such has been the case, due to inadequate exposure of the strata. The former, however well demonstrated to the individual workers, is exceedingly difficult of exposition because of the mutually undescribed, or inadequately described faunas of the Bedford and Kushequa shales (and Knapp sandstones). It seems probable that a facies change in the area of sparse outcrop in northwesternmost Pennsylvania and eastern Ohio, between the typical exposures of the Bedford and Kushequa units, further obscures the correlation.

A comparison of the faunas of the Kushequa shale and the Bedford shale is listed below. The implication is made in these lists that the faunas carry several identical species, as well as many forms which further study may prove to be of the same stock (interfacial or geographic subspecies within a facies province). The faunal lists of the Bedford shale are based on old determinations which were usually somewhat general. Definitely many Knapp forms would have been relegated to Bedford species had they been known thirty years ago. These are, however, of subspecific distinction; apparently the minor differences being engendered by slightly different habitats. This fact in itself strongly suggests the contemporaneity of the two faunas.

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[231] Geologic age of the Bedford shale of Ohio. N. Y. Acad. Sci., Ann., vol. 32, p. 304, 1912.

The Kushequa shale appears to represent the normal neritic zone and its fossils are seemingly exponents of a neritic environment, whereas the Bedford shale seems to represent a subneritic zone, which might be compared remotely to the borderland between the neritic and abyssal zones of non-epicontenintal areas. It is a seaward deposit which is characterized less by shore-loving forms, evidently sturdily adapted for a neritic existence, than by their sub-species (or vice versa) and other forms foreign to a neritic zone, which from their characters might be termed archaic elements. These so-called archaic elements make up that part of the Bedford fauna most emphasized in the past. They have a rather remarkable Hamiltonian stamp. These Hamiltonian elements are not present (or are virtually absent) in the Knapp.[232]

As is indicated on figure 11, the faunal evidence known at present would not justify correlating the entire Kushequa sequence with the entire Bedford sequence, but rather the upper part of the two sequences, especially which carry the Cussewago-Cobham faunal elements. At present it is impossible to say exactly what part, if any, of the Cussewago series the Bedford represents. The faunal evidence leads to a conclusion of contemporaneity, especially between the Bedford and the upper part of the Knapp sequence. It is quite possible that the Bedford also includes the Ohio equivalence of the Hayfield shale and Cussewago sandstone. The purported, and, moreover, commonly accepted correlation of the Hayfield monothem and Cussewago sandstone with the Berea sandstone is far from proven.

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[232] Grave doubt of the actual specific identity of any Bedfordian fossils with Hamiltonian is in the writer's mind. There are, apparently, many mutants within gens which extend back into the Middle Devonian; but it is questionable if identical forms occur in these widely (vertically) separated "formations". An excellent commentary on the community of broad species identification when dealing with facies faunas is shown on Plate 6 of the paper on The Recurrent Tropidoleptus Zones of the Upper Devonian of New York by H. S. Williams (U. S. Geol. Surv., Prof. Paper 79, pp. 98-99, 1913.) The purported representatives of the species **Cypricardella bellistriata** (Conrad) make up a composite "species" of at least four mutants within the **C. bellistriata** gens, if not at least three distinct species within one genetic line. A picture in such broad strokes obscures much detail that is essential to the problem of strata correlation and differentiation.

The Bedford fauna seems as was just mentioned to be a mixture of at least two quite distinct faunal lines. The greater part of the assemblage as known at present is of Mississippian stamp. *Spirifer marionensis* and *Syringothyris carteri* are examples of this younger faunal element. There also occurs an unmistakable Middle Devonian relict faunal element, of which the *Macrodon* aff *hamiltoniae* and species of *Cypricardella* are illustrative.

It is the Mississippian element of the Bedford fauna with which comparison to the Knapp beds is drawn. This element of the Bedford and the fauna of the Knapp monothem seem to have a common immediate heritage. It would seem that the Mississippian elements of the Bedford were derived from a nearer-shore fauna for which the Bedford environment was atypical. The abundant fauna of the Knapp seems to represent the more typical development. Certain it is that the Knapp faunas were neither diluted nor contaminated by the Middle Devonian Hamiltonian relicts.

Much has been made[231] of the Hamilton aspect of the Bedford fauna. This affinity is incontestible for the minor part of the fauna as a simple comparison of some of the species of the Bedford with their almost identical antecedents in the New York Hamilton. The secondary element of the Bedford fauna seems to be a modified (mutated) so-called "recurrent" Hamilton fauna. The Hamilton aspect is most clearly seen in the Ohio province of deposition where conditions were more nearly similar to those which existed in Central New York State at the time of the typical Hamilton accumulation. The Knapp facies, on the other hand, carries in the main the non-Hamiltonian elements of the Bedford fauna. The Knapp formation was accumulated under conditions less similar to those of typical Hamilton deposition. The facies fauna of the Bedford does seem to have a Devonian stamp when compared with only Devonian faunas, but when compared with the hitherto imperfectly known Knapp fauna the Mississippian elements appear to be at least equally indicial. In the parallel columns below the fauna of the Bedford shale is compared with that of the Knapp formation of western Pennsylvania. Unfortunately, many of the Knapp forms are as yet undescribed, though abundantly represented in the writer's collection.

THE BEDFORD FAUNA	KNAPP EQUIVALENT
Lingulodiscina n. sp.	Idem
Lingulodiscina newberryi Hall (?)	Idem
Phyllopod crustaceans (Genus?)	?
Schuchertella herricki Foerste	Schuchertella sp. (Schellwienella sp. ?)
Chonetes n. sp.	Chonetes sp., (several varieties
Productella pyxidata n. var.	Productella sp., (2 n. sp.)
Strophalosia sp.	Productus ? (sessile?)
Rhipidomella n. sp.	Rhipidomella n. sp.
Cranaena ? aff. subelliptica H. and C	?
Cryptonella sp (?)	?
Camarotoechia sappho Hall	Camarotoechia orbicularis ?
Delthyris n. sp., aff. sculptilis Hall and missouriensis Weller	?
Spirifer aff. marionensis Shumard	Spirifer marionensis ? and mutants in the S. disjunctus gens.
Syringothyris carteri Hall	Syringothyris carteri ?
Nucleospira ? sp.	?
Camarospira ? sp.	?
Athyris aff. hannibalensis Swallow	Athyris sp.
Athyris aff. fultonensis Swallow	?
Paleoneilo bedfordensis Meek	Paleoneilo n. sp.
Leda diversa Hall	Leda ? n. sp.
Solenopsis ? sp.	?
Pterinopecten ? n. sp.	Pterinopecten n. sps.
Macrodon hamiltoniae Hall (??)	?
Edmondia aff. subovata Hall	Idem, and E. n. sp.
Edmondia ellipsis Hall	Edmondia aff. ellipsis
Cypricardella aff. gregaria Hall	?
Cypricardella tenuistriata Hall	?
Sphenotus aff. cuneatus Conrad	Idem; Idem, mut; S. n. sp.
Sphenotus contractus Hall	Sphenotus contractus ?
Pholadella newberryi Hall (?)	?
Ptychodesma sp. (?)	?
Bellerophon aff. pelops Hall	Bellerophon, 2 n. sp.
Bellerophon maera Hall	Idem
Bellerophon jeffersonensis Weller	?
Tropidodiscus aff. acutilira Hall	Tropidodiscus ? sp.
Tropidodiscus brevilineatus Conrad	?
Tropidodiscus cyrtolites Hall	?
Oehlertella pleurites Meek	Idem, and O. n. sp.
Oehlertella n. sp.	?
Pleurotomaria aff. sulcomarginata Conrad	Pleurotomaria sp.
Platyceras sp.	Platyceras, several species
Loxonema ? sp.	Loxonema ? sp.
Conularia aff. newberryi Winchell	Conularia sp.
Hyolithes sp.	Hyolithes ? sp.

Orthoceras sp.	Orthoceroids, several
Goniatites sp.	?
Proetus ? sp.	?

The Bedford fauna is essentially that of G. H. Girty[161]; the Knapp fauna our own determination, both above and in the lists to follow. To Girty's list may be added the species listed by C. R. Stauffer in C. S. Prosser's[233] report on the Devonian and Mississippian of Ohio. Stauffer emphasizes the close parallelism between the Bedford fauna of Ohio and that of the Glen Park limestone which Stuart Weller described[234] from the Mississippian basin. Those forms on Stauffer's list which do not appear in the previous one follow below:

BEDFORD FAUNA	KNAPP EQUIVALENT
Productella cf. concentrica Hall	Productella sp. ? (?Idem)
Rhipidomella cf. missouriensis (Swallow)	?
Nucleospira aff. minima Weller	?
Schuchertella chemungensis (Conrad)	Idem, mutant
Ambocoelia umbonata (Conrad) (?)	?
Lingula mecki Herrick (?)	Lingula, several species
Microdon cf. reservatus Hall	?
Nucula cf. glenparkensis Weller	Nucula (?) sp.
Parallelodon hamiltoniae Hall	?

In addition to the species recorded in Girty's and Stauffer's lists the following species are recorded by H. P. Cushing[235] from the Bedford shale of the Cleveland district, Ohio:

Lingula meeki ?
Orbiculoidea hertzeri
Schuchertella morsei
Camarotoechia kentuckyensis
Cryptonella n. sp.
Athyris aff. lamellosa
Ambocoelia norwoodi
Leda n. sp.
Parallelodon irvinensis
Cypricardella n. sp.
Prothyris n. sp.
Bembexia sp.
Brachymetopus sp.

On the non-Hamilton elements of this fauna largely hinges the determination of the geologic age of the Bedford shale. This matter has previously been described in some detail by G. H.

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[233] The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., Fourth Ser., Bull. 15, pp. 44-45, 1912.

[234] Kinderhook faunal studies, Part IV, The fauna of the Glen Park limestone. Acad. Sci. St. Louis, Trans., vol. 16, pp. 435-471, 1906.

[235] The geology and mineral resources of the Cleveland district. Ohio. U. S. Geol. Surv., Bull. 818, p. 44, 1931.

Girty[231]. On the basis of the dissimilarity of the Bedford and Berea faunas and on the Hamiltonian aspect of some of the species of the Bedford, Girty assigned the Bedford to the Devonian. Although the matter of the age of the Knapp monothem has been discussed at length in the earlier part of this paper, and the Mississippian age apparently established on the basis of disconformity and faunal aspect, and likewise, in the pages just previous an argument has been presented for considering the Bedford as coeval, if not continuous laterally with at least the upper part of the Knapp monothem, still it seems advisable briefly to examine the non-Hamiltonian portions of the Bedford fauna for possible age assignment. It is against the author's conviction to underwrite an assignment of other than Mississippian age to the *Syringothyris* of the Bedford formation. The Bedford *Syringothyris* do not belong in the same line as the Devonian Syringothyrids such as those described by Schuchert[236] from the Devonian of Missouri or to the geographically nearer Syringothyrids of the Panama sandstone at Jefferson, Ohio[237],[238]. The Bedford *Syringothyris "carteri"* is very closely related to the forms occurring in the Knapp monothem, and quite indistinguishable from the species occurring in the Corry sandstone. The Bedford forms seem clearly to be of the Mississippian type, and more specifically, of lower Kinderhookian age.

The relationship of the Cussewago sandstone to the Bedford and the Berea has been another perplexing stratigraphic problem in Ohio and Pennsylvania. The Berea sandstone has been universally conceded to be of Mississippian age. It represents a tripartite sandstone mass derived presumably from the west and northwest and laid down as a shore, or near-shore deposit from west-central Ohio to eastern Warren County, Pennsylvania. From the vicinity of Cleveland eastward the Berea is comprised of two sandstones with a thin shale between. This condition exists nearly to the Pennsylvania line, and has been variously correlated with the Pennsylvania section. M. C. Read[239] mistook the Shenango sandstone and the Sharpsville sandstone, below, for the Berea of Pennsylvania as W. A. Verwiebe[240] has suggested. This was probably the cause for early correlation of the Sharpsville sandstone with the Berea by the Ohio Geological Survey[239]. This correlation was subsequently corrected by I. C. White[241]. Later White concluded[242] that his Oil Lake group of Crawford County, Pennsylvania was the equivalent of the Berea sandstone. The Oil Lake group embraced the strata included in the Corry sandstone downward through the Cussewago sandstone. Many subsequent writers have been in accord with the conclusion that the Corry sandstone represents at least part of the Berea grit of Ohio. Among these are G. H. Girty[243], Edward Orton[244], H. P. Cushing[245], and J. J. Stevenson[246]. Of these Cushing, Girty and Stevenson as well as C. S. Prosser[247] and W. A. Verwiebe[248] concluded that the Corry sandstone, together with the Cussewago shale (Hayfield shale) and the Cussewago sandstone represented the Berea sandstone in Pennsylvania.

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[236] C. S. Schuchert, On the Brachiopod genus Syringothyris in the Missouri Devonian, Am. Journ. Sci., vol. 30, p. 223, 1910.

[237] H. P. Cushing, Age of the Cleveland Shale of Ohio, Am. Journ. Sci., vol. 33, pp. 581-584, 1912.

[238] C. S. Prosser, The Devonian and Mississippian of Ohio, Ohio Geol. Surv., Bull. 15 (Fourth series), pp. 537-539, 1912.

The Berea sandstone in Ohio apparently unconformably overlies the Bedford shale, and so pronounced is this unconformity in places that the pre-Berea scour has cut down through the entire thickness of the Bedford shale and into the top of the underlying Cleveland shale. Such unconformities have been described by W. G. Burroughs[249] and C. S. Prosser[250] in several places in Central Ohio. In most places, however, it appears that the Berea is at most only disconformable with the Bedford formation. J. E. Hyde[251] and Edward Orton[244] are impressed by the conformability of the two formations. To them the two formations seem to be different phases of a single sedimentary cycle. To quote from J. E. Hyde[251], "The Berea of southern Ohio is only a phase of the Bedford of the same region . . ."; he then goes on to point out that the Bedford of northern Ohio, although distinctly delimited, is identical lithically with this Bedford "Berea." The unconformable contact of the two formations in Central Ohio is perhaps but another illustration of the principle that the conditions under which a sandstone in the midst of shales is accumulated are usually such that a greater or lesser amount of "scour and fill" takes place. This latter suggestion is further substantiated by the similar conclusions arrived at by J. E. Hyde after his study of the Waverly formations of south and central Ohio[252].

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[239] Report on the geology of Ashtabula, Trumbull, Lake and Geauga Counties. Ohio Geol. Surv., Report I, part 1, Geology, p. 483, and pp. 505-508, 1873.

[240] The Berea formation of Ohio and Pennsylvania. Am. Journ. Sci., (4), vol. 42, p. 45, 1916.

[241] The geology of Mercer County. Second Penna. Geol. Surv., Report Q3, p. 124, 1881.

[242] The geology of Erie and Crawford Counties. Second Penna. Geol. Surv., Report Q4, p. 91, 1881. See also a discussion of the problem by C. S. Prosser, The Devonian and Mississippian formations of northeastern Ohio. Ohio Geol. Surv., Fourth Series, Bull. 15, p. 355, 1912.

[243] Geologic age of the Bedford shale of Ohio. N. Y. Acad. Sci., Annals, vol. 32, pp. 295-319, 1912.

[244] Geology of Ohio. Ohio Geol. Surv., vol. 7, p. 33, 1894.

[245] Notes on the Berea grit in northeastern Ohio. Am. Assoc. Adv. Sci., Proc., vol. 36, p. 215, 1888.

[246] Lower Carboniferous of the Appalachain basin. Geol. Soc. Amer., Bull., vol. 14, p. 41, 1903.

[247] Ohio Geol. Surv., Fourth Series, Bull. 15, p. 355, 1912.

[248] The Berea formation of Ohio and Pennsylvania. Am. Journ. Sci., vol. 42, p. 46, 1916.

In resumé, the Berea formation of Ohio which is composed of three members northeast of Cleveland, might tentatively be correlated in the order shown on the parallel tables, below. The column numbered (1) indicates what is held to be the more likely correlation, but that indicated by (2) is not wholly disproven.

Ohio	1	2
Upper Berea sandstone	Corry sandstone	
Berea shale	Hayfield shale	
Basal Berea sandstone	Cussewago sandstone	Corry sandstone
Bedford shale	Kushequa shale	Hayfield shale Cussewago sandstone, etc.

[249] Berea sandstone in eroded Cleveland shale, Journ. Geol., vol. 22, pp. 766-771, 1914, and The unconformity between the Bedford and Berea formations in northern Ohio. Idem, vol. 19, pp. 655-659, 1911.

[250] The Waverly formations of Central Ohio, Amer. Geol., vol. 34, pl. 19; fig. 6, 1904; The disconformity between the Bedford and the Berea formations in entral Ohio. Journ. Geol., vol. 20, pp. 585-604, 1912; and various places in Ohio Geol. Surv., Fourth Series, Bull. 15, 1912.

[251] The ripples of the Bedford and Berea formations of Central and southern Ohio, with notes on the paleogeography of that epoch. Journ. Geol., vol. 19, pp. 257, 258, 1911.

[252] Stratigraphy of the Waverly formations of central and southern Ohio. Journ. Geol., vol. 23, pp. 655-682; 757-779, 1015.

THE CONTINUOUS SECTION ALONG THE ALLEGANY RIVER

In 1908 Charles Butts[253] undertook to summarize the Pre-Pennsylvanian stratigraphy of northwestern Pennsylvania for the Pennsylvania Topographic and Geologic Survey Commission. This work was accomplished largely through the medium of a "continuous section" of the strata exposed along the Allegany River from the New York state boundary to the village of Emlenton, south of Oil City, Pennsylvania. This section beautifully illustrated the relationship of the Upper Devonian and Lower Mississippian rocks in that part of northwestern Pennsylvania. While as a whole this section is exceedingly useful and instructive there are certain minor deficiencies which must be remedied. This is now possible largely due to the many exposures which by the intervening twenty-five years of road construction have been uncovered.

Before emending the river section it is of interest to note that in this paper of 1908 Butts forsook his 1903 correlation of the Knapp beds of New York State with the Mississippian of northwestern Pennsylvania[254]. The intervening research of G. H. Girty (in 1908 not yet published) had seemed to demonstrate the Devonian age of the Knapp formation. This recantation by Butts has been the cause behind the varied classification of these Knapp beds which one meets in textbooks and stratigraphic papers. In his 1908 paper Butts classified the Knapp beds as Upper Devonian (Catskill-Erie shale). It was in this paper that Butts first described the Conewango "formation", the delimitation of which, as originally conceived, proves to have been very astute.

The Allegany River section which was the main contribution of this report, was a continuous section along the Allegany for a distance of some seventy miles south of the New York State line. In the main this continuous section is extremely enlightening and exceedingly useful. However, in the middle part of the traverse, for a few miles north and south of Tidioute, Pennsylvania, a most critical area, the section is not wholly in accord

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[253] Pre-Pennsylvania Stratigraphy. Penna. Topographic and Geol. Surv. Comm., Report for 1906-1908, pp. 190-200, and diagram, 1908.

[254] Fossil faunas of the Olean quadrangle. N. Y. State Mus., Bull. 69, pp. 990-996, 1903.

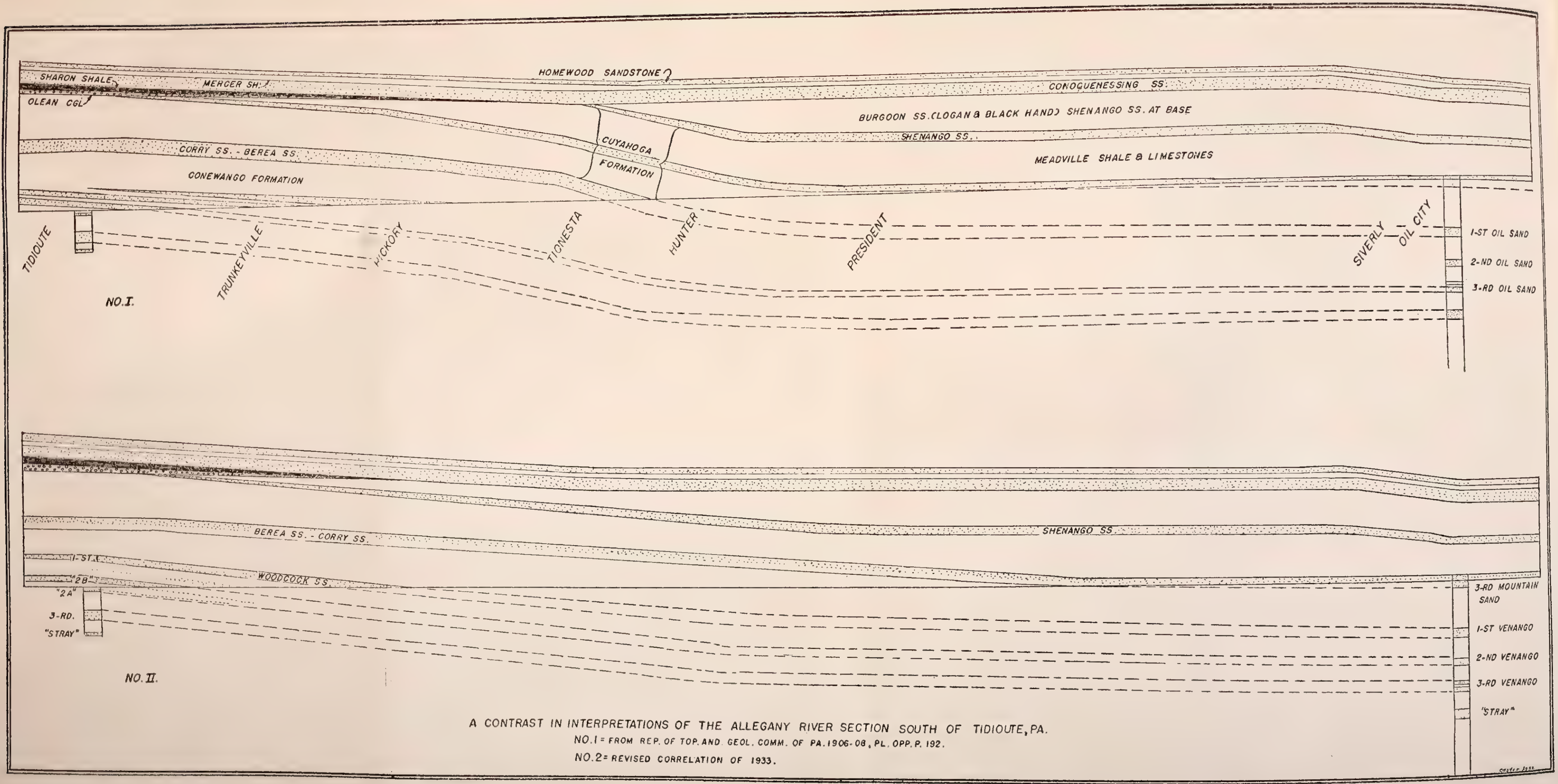
SHARON SHALE
MERCER SH.
OLEAN CGL.
HOMEWOOD SANDSTONE ?
CONOQUENESSING SS.
BURGOON SS. (LOGAN & BLACK HAND) SHENANGO SS. AT BASE
SHENANGO SS.
CORRY SS. - BEREA SS.
CUYAHOGA FORMATION
MEADVILLE SHALE & LIMESTONES
CONEWANGO FORMATION
TIDIOUTE
TRUNKEYVILLE
HICKORY
TIONESTA
HUNTER
PRESIDENT
SIVERLY
OIL CITY
1-ST OIL SAND
2-ND OIL SAND
3-RD OIL SAND
NO. I.
BEREA SS. - CORRY SS.
SHENANGO SS.
1-ST.
WOODCOCK SS.
"2B"
"2A"
3-RD.
"STRAY"
3-RD MOUNTAIN SAND
1-ST VENANGO
2-ND VENANGO
3-RD VENANGO
"STRAY"
NO. II.
A CONTRAST IN INTERPRETATIONS OF THE ALLEGANY RIVER SECTION SOUTH OF TIDIOUTE, PA.
NO. 1 = FROM REP. OF TOP. AND GEOL. COMM. OF PA. 1906-08, PL. OPP. P. 192.
NO. 2 = REVISED CORRELATION OF 1933.
Caster 1933

Fig. 12.—The rock section exposed along the Allegany River from Tidioute to Oil City, Pennsylvania. The upper diagram is from Charles Butts (1906). The lower represents the present interpretation.

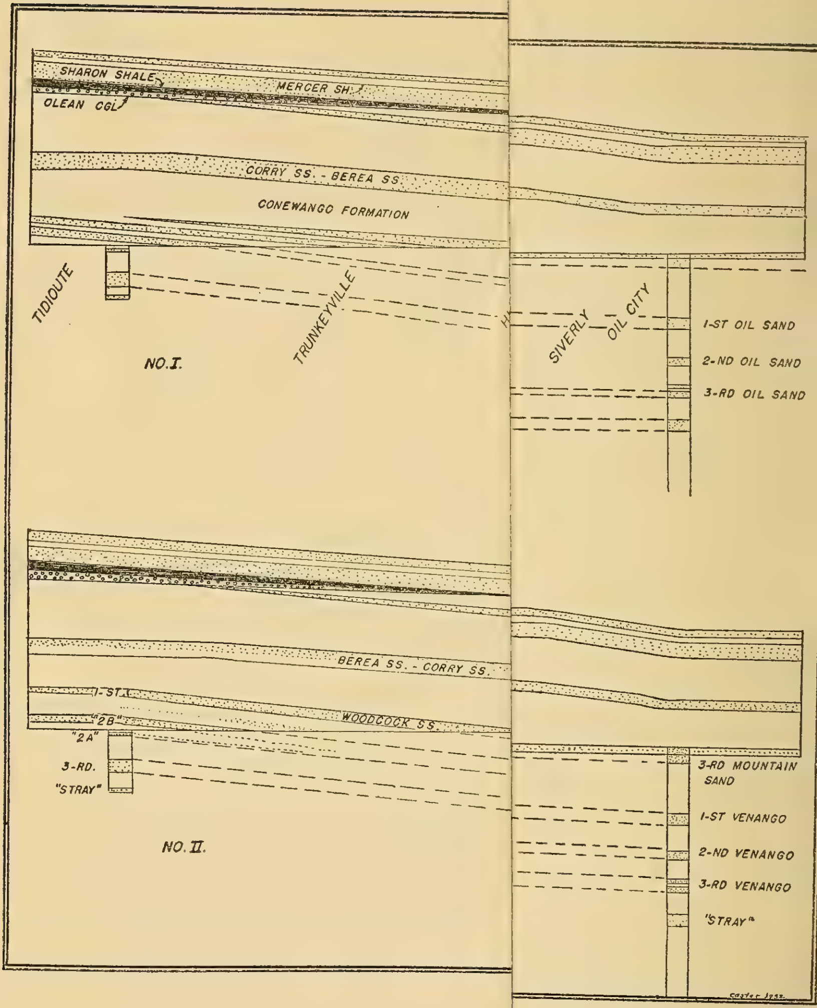
SHARON SHALE
MERCER SH.
OLEAN CGL.
CORRY SS. - BEREA SS.
CONEWANGO FORMATION
TIDIOUTE
TRUNKEYVILLE
SIVERLY
OIL CITY
NO. I.
1-ST OIL SAND
2-ND OIL SAND
3-RD OIL SAND
BEREA SS. - CORRY SS.
1-ST
WOODCOCK SS.
"2 B"
"2 A"
3-RD.
"STRAY"
NO. II.
3-RD MOUNTAIN SAND
1-ST VENANGO
2-ND VENANGO
3-RD VENANGO
"STRAY"
Caster 1932

Fig. 12.—The rock sec

Charles

with the field facts discovered in this restudy. The problem of making this continuous section was a most trying one in 1908. To-day, even, it is a difficult matter to follow strata continuously along the river, although there are a great many new exposures made by extensive highway construction. For some unexplained reason, probably a book-keeping fallacy, a monoclinal flexure is introduced into the section a few miles below Tionesta. (See upper diagram of figure 12.) From personal and corroborated study of the area no evidence for such a flexture can be found.[255]

In the rock sequence at Tidioute, Pennsylvania, as shown by Butts and others the strata of the left hand columns, below, are present. A few miles south of Tidioute the sequence shown in the right hand columns of the following lists is found. Figure 12 illustrates the discrepancy in past and present correlations of the same section along the Allegany.

Correlation of the 1908 report

Connoquenessing sandstone	Connoquenessing sandstone
Absent by disconformity	Burgoon sandstone
Absent by disconformity	Shenango sandstone
Shale and sandstone	Meadville shales
Sandstone (in the Cuyahoga)	Sandstone (in the Cuyahoga)
Shale and sandstone	Shale and sandstone
Corry sandstone	Corry sandstone
Shale	Shale (river level)
Sandstone	Sandstone
Shale	Shale
Sandstone (river level)	Sandstone

Present revised correlation

Connoquenessing sandstone	Connoquenessing sandstone
Shale and sandstone	Burgoon sandstone
Sandstone ("in the Cuyahoga")	Shenango sandstone
Shale and sandstone	Meadville shale
	Sandstone ("in the Cuyahoga")
	Shale and sandstone

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[255] The presumable explanation of this error, and one to which Mr. Butts is now prone to subscribe (personal communication 1932) is that in taking down notes on dip and strike while pacing the railroad track along the river no mention was made of the fact that the river makes a very sharp bend at this point and for a considerable distance tends to follow along the direction of strike rather than dip. Rock sections are sparse for a few miles along here, and in rapid work precise identification of the strata might go amiss. At any rate a flexure such as would have proved a bonanza to oil drillers was drawn in. Only dry holes occur where this structure should be, and the stratigraphic relations at Oil City are such that constant or virtually constant dip may be assumed.

Corry sandstone	Corry sandstone
Shale	Shale (river level)
Sandstone	Sandstone
Shale	Shale
Sandstone (river level)	Sandstone

In other words, there is serious ground for doubt of the existence of the "sandstone in the Cuyahoga" which is recorded in the 1908 report. Many sections have been made in the area and the conclusion is that the "sandstone in the Cuyahoga" is really the Shenango sandstone at Tidioute. The stratum which Butts determined as the "sandstone in the Cuyahoga" south of Tidioute is the Corry sandstone. The Corry is exposed along the regional strike, a few feet above water level to the mouth of Oil Creek at Oil City. Many exposures occur along Oil Creek. The Corry sandstone is therefore obviously not the Venango first oil sand of Oil City. The upper Conewango conglomerate lens which the 1908 report shows as entering the Tidioute area from the south is the Woodcock sandstone and is well exposed in Dennis Run at Tidioute. The Woodcock sandstone occupies the position of the Venango first oil sand in the region, and is below the surface in the correct position for this sand at Oil City.

In other words, the whole difficulty in correlation is obviated if the monoclinal flexure below Tionesta is erased, as shown on the lower diagram of Figure 12. In fact it would almost seem by placing a straight-edge on the original diagram that the sketch was originally correctly drawn and subsquently the non-existent local steepening added.

The correlation of the Salamanca conglomerate with the third Venango sand is hard to understand in the light of this section. Yet such was the conclusion formulated by Butts in the Warren Quadrangle report in 1910. The Salamanca conglomerate suite was traced by Butts in 1908 for the first time from the New York State line into the Warren area. Continuing the tracing along the river, which is somewhat simpler in these days of extensive highway excavations, it develops that the Salamanca suite is the Second oil sand group at Tidioute, not the third. The Third is beneath the water level, and productive of oil. In fact, in Dennis Run at Tidioute all *three* oil sands are actually productive. The first sand is the Woodcock, the second the Salamanca suite and the third the Panama conglomerate.

THE MISSISSIPPIAN FORMATIONS OF OHIO AND PENNSYLVANIA, A REVIEW

In the years 1916-1917 W. A. Verwiebe[256],[257],[258] published several papers on the stratigraphic relations of the Devonian and Mississippian strata in northwestern Pennsylvania and eastern Ohio. These articles were of a revisionary nature and much valuable new information was included in them. However, during the course of the present investigation certain errors which are fundamentally misleading have been detected.

The difficulty of too few exposures which previous workers have encountered is somewhat improved today as a result of the great impetus to road construction in this part of Pennsylvania during the past few years. A great many new exposures are now available. A second advantage which present workers have is a somewhat more complete knowledge of the fossil faunas of the area.

Many of Verwiebe's correlations are at fault, first, because of injudicious acceptance and rejection of portions of the erroneously interpreted Allegany River section of the 1908 report of Butts[253], discussed above, and second, because of failure to heed faunal evidence. Due to oversight of the characteristic Berea (Corry) fauna, Verwiebe's discussion of the Berea formation is sometimes based on exposures of the true Berea sandstone (Corry) and again on exposures of the overlying Shenango sandstone. The Shenango and Corry sandstones are lithically quite similar on the Allegany River in Warren County, but faunally very distinct. In this correlation error Butts and Verwiebe concur. The correlation conclusions outlined on page 43 of Verwiebe's first paper[256], which pertained to the Berea sandstone, were:

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[256] The Berea formation of Ohio and Pennsylvania, Am. Journ. Sci., vol. 42, pp. 43-58, 1916.

[257] Correlation of the Mississippian of Ohio and Pennsylvania, Idem, vol. 43, pp. 301-318, 1917.

[258] Correlation of the Devonian shales of Ohio and Pennsylvania, Idem, vol. 44, pp. 33-47, 1917.

> (1) "The Berea sandstone is the equivalent of the Cussewago sandstone, Hayfield shale, and Corry sandstone in Pennsylvania."

This is perhaps correct, and at present incontestable.

> (2) "The Corry sandstone increases in thickness across Crawford County to the Allegany River where it is 50 feet thick."

This is erroneous. The Corry sandstone is easily recognizable along the Allegany River, especially in the Tidioute area (Dennis Run section[168] is of especial excellence) where it is not over 5 feet thick, and grades into underlying shales as explained on previous pages herein. The fauna and lithology of the 5 foot layer of Corry sandstone of the Tidioute area is identical with the type Corry exposure in the Colegrove quarries at Corry, Pa. The sandstone which Verwiebe referred to as the Corry on the Allegany River is in reality the Shenango, which in southern Warren County, Pa., is a buff colored to whitish, pebble-bearing, fossiliferous (but not the Corry fauna, see previous list) sandstone, approximately 50 feet thick and lying some 150-200 feet above the true Corry. The Shenango is well shown along the Tidioute-Enterprise road about 5 miles south-southwest of Tidioute. It is also shown above the true Corry in repeated outcrops along the steep river banks from Tidioute southward to Oil City and Franklin, Pa.

> (3) "The Corry sandstone increases in coarseness eastward and is a coarse pebble rock on the Allegany River."

This is erroneous as explained above. The true Corry is surprisingly homogeneous throughout its lateral range in western Pennsylvania. It is a light colored, fine sandstone. Small pebbles have been observed only in the extreme eastern development in eastern Warren County, Pa., near Big Bend. Nowhere has it been observed to be truly conglomeratic. The Shenango sandstone is conglomeratic, however.

> (4) "The Corry sandstone is universally underlain by a limestone; this has been a very useful guide in correlation work throughout western Pennsylvania."

This limestone beneath the Corry would be the Littles Corner limestone of this report. The Littles Corner limestone is of very local occurrence in the Hayfield shale of Crawford County and is not present in recognizable form on the Allegany River, nor for a long distance west of there in any of the many sections (all of Verwiebe's in the area and others) which were examined in the course of this revisionary study. In some instances of correct identification of the Corry sandstone, the limy layer at the base of the Corry which carries the highly characteristic fauna may have been observed by Verwiebe. This is, however, rather unlikely inasmuch as a good development of this same limy fossil zone was not observed in the type occurrence of the Corry sandstone in the Colegrove quarry at Corry, Pennsylvania. The limestone to which Verwiebe possibly had reference in many of his sections is the *Upper Meadville limestone* (*French Creek limestone* of this report) which is remarkably persistent and occurs not far below the Shenango sandstone throughout Crawford County and at Oil City as well. It is not yet proven that the French Creek limestone is present on the Allegany at Tidioute. If so, it is altered very materially. (At any rate, it is not represented by the "fossil bands" of I. C. White[198] as explained previously.) There is rather marked similarity between the true Cussewago limestone (Littles Corner) of the Meadville area and the French Creek; it is understandable how elsewhere they might be confused.

> (5) "The Cussewago sandstone thins out and disappears from the section about Longitude 80 degrees, 5 minutes west, though it may be represented farther east by a part of the shales and sandstones underlying the Corry."

This statement is highly ambiguous, but the facts are that the Cussewago sandstone disappears from the section *southward* by the assumption of a shale facies or by lensing, but is remarkably persistent east and west from the eastern counties of Ohio where Prosser's sections[259] seem to indicate its presence at the base of the Berea sandstone. The Cussewago is present through Meadville, Pa., continuously present to Warren, Pa., and on into the central and eastern part of McKean County where it has been known as the upper Knapp conglomerate (Cobham conglomerate of this report).*

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[259] C. S. Prosser, The Devonian and Mississippian of northeastern Ohio, Ohio Geol. Surv., Fourth Series, Bull. 15, 1912.

> (6) "The Corry sandstone is represented on the Allegany River by a sandstone 160 feet higher in the column than the Corry as identified by Butts in his Allegany River section."[253]

This statement has been discussed above. The sandstone which Verwiebe identified as the Corry, (but for which he occasionally mistook the true Corry) is the Shenango sandstone on the Allegany River. (The persistent "sandstone in the Cuyahoga"[253] of Butts is apparently also the Shenango or a myth).

> (7a) "The Berea sandstone is absent north of Tidioute, along the Allegany River."

This is consistent, though erroneous, for what is meant is, that the sandstone which was being identified as the Corry at Tidioute disappears north of Tidioute. This is true. The Shenango sandstone does disappear beneath the Pottsville unconformity not far north of Tidioute, Pa., and is not present at Warren, Pa. The second part of the seventh conclusion is that:

> (7b) "The fossiliferous band which Butts stated[68],[253] was the Warren equivalent of the Corry sandstone, is the surface equivalent of the Venango first oil sand."

This has been shown to be erroneous in the previous discussion of Butts's paper. First, Butts was *correct* in his acceptance of G. H. Girty's identification[231] of the fossiliferous band as belonging to the Corry sandstone. The fauna is conclusive as has been explained elsewhere in this report. Second, Butts correlated this band with the Venango first oil sand, as a glance at his continuous section from Warren to Oil City will show, and with him Verwiebe concurred. Butts's correlation was erroneous, as was shown above. In the Dennis Run section at Tidioute both the Corry and the underlying Woodcock (Venango first oil sand) are well exposed. The Corry is the "third mountain sand" of the oil well drillers along the Allegany River in the Warren and Venango areas.

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*Long before this conglomerate was given the name Knapp it had been termed the "Sub-Olean" conglomerate of McKean County, Pennsylvania by the geologists of the Second Survey. In fact, the initial usage of the term "Sub Olean" was for the conglomerate subsequently termed Knapp.

The evidence cited by Verwiebe for the correlations made in his paper are lithologic, paleontologic and stratigraphic. It is unfortunate that the Corry sandstone in the type locality at Corry had not yet undergone sufficient weathering to make obvious the rich fossil fauna included in it. At present the shells show up most clearly. This rich fauna makes the statements of the barrenness of the Corry seem to-day a little preposterous.

The Cussewago sandstone is of surprisingly constant lithology in Crawford and Warren Counties of Pennsylvania. It is not especially lenticular. Cussewago of typical "millet grain" lithology occurs in the area about Warren, Pennsylvania. Verwiebe attempted to place the Berea in the Pennsylvania section on the basis of the fauna of the supposed equivalent of the black Sunbury shale which overlies the Berea in Ohio. Lingulae and Discinae are the only fossils, and these abound throughout the whole Crawford series in Pennsylvania. To date no one has satisfactorily identified the Pennsylvania equivalent of the Sunbury shale of Ohio.

The Shenango sandstone undergoes rather marked lithologic change as it is followed northward along the Allegany River from Oil City so that near Tidioute it is no longer as outstandingly charged with iron as in the Franklin and Oil City region and is more conglomeratic. This facies change may have been a confusing element inasmuch as the author of the paper under discussion says that the Shenango is of uniform lithology.

The correlations throughout the paper are not always erroneous, but this lack of consistency makes the rendering of credit except by page and line almost impossible. In many sections, as at Baum, Pennsylvania, Verwiebe reported a true development of the Corry sandstone, and not the Shenango sandstone with which he was confusing the Corry a little further north. The corrections which Verwiebe made of the correlations of Butts in his antecedent report seem to be correct at first sight, but on closer study it develops that in interpretation of field evidence, Verwiebe was in accord with Butts. His corrections were, as it materializes, unjustified nomenclatorial corrections. The "Corry sandstone" of Butts, Verwiebe decided was not the same as the true Corry. It so happens that Butts was correct in this correlation. The Corry sandstone Butts included in the top of the Knapp Sandstone, and correlated with the Venango first oil sand to the south. Verwiebe also correlated this member with the Venango first oil sand. Both seem to be in error in this matter.

The correction here made is that the field relations, irrespective of the names applied to the formations, are such that the fossiliferous band (the true Corry) 15+ feet *above* the Knapp conglomerate at Warren (which Verwiebe considered part of the Knapp) is exposed at the surface on Oil Creek and the Allegany River at Oil City instead of being beneath the surface at the position of this fossil band as the Venango first oil sand at Oil City. Both Butts and Verwiebe affirm the sub-surface position of this fossil band as the Venango first oil sand at Oil City. The Knapp conglomerate does not continue in a conglomeratic facies as far south as Tidioute on the Allegany, and is therefore not available for a sub-surface oil reservoir further south.

Inasmuch as elsewhere in this report, under the discussion of strata in the aforegoing catalogue, oil sand correlations, as at present understood, have been explained, this part of Verwiebe's paper need not be discussed here. The true Corry sandstone is the "third mountain sand" of the Venango area, and overlies the first oil sand, (which is presumably the Woodcock), by more than 100 feet. This relation is well shown in the Dennis Run Section.

CORRELATION OF THE MISSISSIPPIAN OF OHIO AND PENNSYLVANIA, A SECOND REVIEW

Following on the conclusions arrived at in his first paper, Verwiebe undertook in his second paper[257] to present an exposition and revision of the correlation of the Mississippian formations of Ohio and Pennsylvania. In this paper, as in the preceding, the Berea was inadvertantly correlated with the Shenango sandstone on the Allegany River in the Tidioute area, which may be thought of as the locus from which Verwiebe worked. Here will be taken up in detail only his discussion of the Berea formation. His discussion of the Shenango and underlying formations was based on the type sections where his observations were astute. In the case of the Berea, much was made of its non-fossil bearing nature, and it was stated that from an examination of all the reported Pennsylvania occurrences of the Corry could be vouchsafed its non-fossility. The famous locality of fossiliferous Corry sandstone mentioned by I. C. White as "on the road to Enterprise"[260] Verwiebe visited and concluded was the Venango first oil sand, and not the Corry at all. As a matter of fact, it is the Corry. White was correct. Another famous Corry locality, that of Cobham Hill on the Warren quadrangle, which Butts described as Corry sandstone, and from which Girty[231] made his main Berea (Corry) faunal collections, Verwiebe concluded was not Corry, but a sandstone 180 feet below the Corry, the Venango first oil sand. Butts and Girty were, however, quite right in correlating this fossiliferous zone with the Corry.

The remainder of the paper undertook to prove that the Berea sandstone marks the base of the Mississippian system in Pennsylvania and Ohio. It is exceedingly difficult to discuss this conclusion in detail. The major premise that the Berea is the basal Mississippian is not true if the facts brought out in this present restudy are correctly interpreted, but aside from this, the fact that many of his arguments were based upon observations of the Shenango sandstone in mistaken identification for the Corry invalidated this conclusion. Verwiebe and Girty concurred[231] in assigning the Bedford shale to the Devonian. The present grounds for dissention from this latter contention have been discussed above.

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[260] The geology of Crawford and Erie Counties, Second Penna. Surv., Report Q 4, p. 92, 1881.

If the Berea stage is composed of the Corry sandstone, the Hayfield shale and includes the Cussewago sandstone at its base as Verwiebe states, and if furthermore the Cussewago sandstone intergrades completely (i.e., faunally and lithically) with the underlying Kushequa shale (upper Riceville of old) in the Warren area, as has been herein described, then this lower shale must be admitted to the Mississippian system. Prosser and others have suggested[259] that the Cussewago sandstone similarly intergrades in a few places in Ohio with the underlying Bedford shale. It appears, as stated above, that there is reasonable support for the view of continuity, or at least contemporaneity of the Bedford and the Kushequa shales. The disconformity at the base of the Bedford and the Kushequa is a convenient and also the logical place to draw the boundary line between the Mississippian and Devonian systems. The only alternative horizon would be at the top of the Cussewago sandstone and therefore presumably in the midst of the Berea sandstone.

In his third paper[258] on the correlation of the Devonian shales of Ohio and Pennsylvania, Verwiebe presents a very useful correlation work. It is noteworthy, however, that in this paper no mention is made of the Venango first oil sand which had been so extensively dealt with in previous papers.

CONCLUSION

The preceding pages have recorded a four-fold attempt at stratigraphic clarification of the Upper Devonian and Lower Mississippian rocks in northwestern Pennsylvania. The Catalogue of Strata has been an attempt concisely to present the characteristics of the stratigraphic units of the area. On the basis of the facts there presented correlation of the rock units in northwestern Pennsylvania with adjoining areas has been attempted. As a result of the close study herein recorded it has appeared necessary to reclassify a large portion of the strata.

Nomenclature must show relationship, and solely with this in mind have classificatory changes been made. As a part of the classificatory revision a brief outline of facies relationship has been presented. It was finally felt necessary to review some of the more pertinent previous works on the stratigraphy of the region, largely because the present concepts are at times greatly out of accord with former views.

In many parts this report takes on the aspect of an abstract account of results. For the fuller exposition of these conclusions the reader is referred to the faunal studies which will appear in the course of the year (1934), it is hoped. Judgment on many conclusions obtained herein must be held in abeyance until the faunal monographs are completed. The work on these has been in progress for the major part of four years. This report may be viewed as a stratigraphic prelude to the detailed faunal studied which shall constitute the succeeding parts of this restudy, of which this is the first.

SUMMARY AND RECAPITULATION

In view of the paucity of detailed information available on the stratigraphic geology of the surface strata of northwestern Pennsylvania and the conflicting nature of much of the information that is available, it has been deemed necessary herein to present a somewhat detailed account of what is known at present from field familiarity with the strata and a preliminary study of the faunas.

The area embraces the westernmost extent of the encroachment of the Catskill delta over New York and Pennsylvania. The evidence of this area would seem materially to strengthen the proof of the former miscorrelation of the eastern deltaic facies of Upper Devonian marine beds as has recently been indicated by G. H. Chadwick, Bradford Willard, G. A. Cooper and others. Because of the perfection of the facies relationship in northwestern Pennsylvania, it has been possible to offer illustrative material for a somewhat original method of facies nomenclature. This method may be equally well applied to eastern strata when they are thoroughly studied. Two facies categories are recognized: a larger or magnafacies, which comprises a complete "lithic unit", and smaller units or components of the magnafacies between time or contemporaneity planes, which are termed parvafacies. Geographic names, largely selected from names which would otherwise be synonyms of stratigraphic terms, are used for the parvafacies. Strong dissention is voiced to the usage of accepted *stratigraphic* names for facies terminology, a usage which has very recently been proposed[261].

The faunas are found to more closely follow the facies province migration than either vertical or horizontal components of a given series of sections.

On the basis of new facts brought out by faunal studies and by the discovery of nonconformable field relationships, it becomes essential that certain modifications be made in the accepted classification of strata at the top of the Devonian and the base of the Mississippian. The major of these suggested alterations is a proposal to abandon the term Bradfordian series and to establish an Upper Devonian, Conewango series and a basal Mississippian, Cussewago series out of the strata formerly included in the abandoned series. The Oil Lake series is also proposed for the Mississippian strata above the Cussewago and argument presented for the reinstatement of the Crawford series of writers.

In the catalogue of strata a systematic description of the upper Devonian and lower Mississippian strata is given. Several new members are differentiated and described. Characteristic faunas are briefly described.

This is followed by an attempt at correlation of the upper Chagrin and Bedford formations of Ohio with the Conewango and Cussewago series of Pennsylvania respectively. The correlation of the various members of the Conewango and the Chagrin is definitely established. Among other correlations proven is that of the *Syringothyris* beds near Jefferson, Ohio, with the Panama conglomerate at the base of the Conewango of New York and Pennsylvania.

The problem of Bedford and Knapp correlation is outlined in detail and pertinent suggestions offered, although finality must await more detailed faunal study of the Bedford shale.

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[261] G. H. Chadwick, Great Catskill delta, Pan Amer. Geol. vol. 60, p. 107, 1933.

The problem of oil-sand and surface member correlation in the Venango oil zone of Pennsylvania is discussed and certain errors corrected. This was possible through the careful tracing of the Corry sandstone fauna over a very wide area.

PROBLEMS MERITING EARLY CONSIDERATION

This lengthy and somewhat detailed account of stratigraphic relations in Pennsylvania leaves us virtually as far from the mirage of finality as we were before it was written. The crucial problems are still many:—the final solution of each hinges on the completion of several lines of research. The shortage is in workers, not in work. Some of the more urgent problems are:

1. Outstanding in importance today is the necessity of careful, systematic tracing of Chautauquan, Conewangoan and in so far as possible, Cussewagoan strata, eastward toward the source of the Catskill delta. In conjunction with this keystone problem, other tracings must be made to the south and southeast.
2. Thorough revision of the Chautauquan faunas in the light of the recent stratigraphic discoveries and hand in hand with still further study of the Catskill facies is necessary.
3. Of prime importance also is a mongraphic study of facies relationship based on the Middle and Upper Devonian of New York, Pennsylvania and eastern Ohio. This area probably represents as perfect exposure of facies development as any place on earth. A great basic work on the phenomena of facies variations should be founded on this rock sequence.
4. A faunal study of the rocks comprising the Oil Lake series will be a fertile research problem. Wonderfully rich faunas occur in these strata, abundant exposures and easy collecting. Strange that they have been so long neglected! In the main, the faunas are comprised of undescribed species.

5. The faunas of the Bedford shale and of the Chagrin shale, as well as the invertebrate fauna of the Cleveland shale and Berea sandstone of Ohio are all virtually unknown. On them some of the most important stratigraphic correlations and time determinations of this area hinge.

6. By no means the final or least problem is the detailed study of the Pocono and Mauch Chunk problem of Pennsylvania and the Appalachain trough in general, as has been previously outlined. This must necessarily be prefaced by detailed study of the type Pocono and Mauch Chunk.

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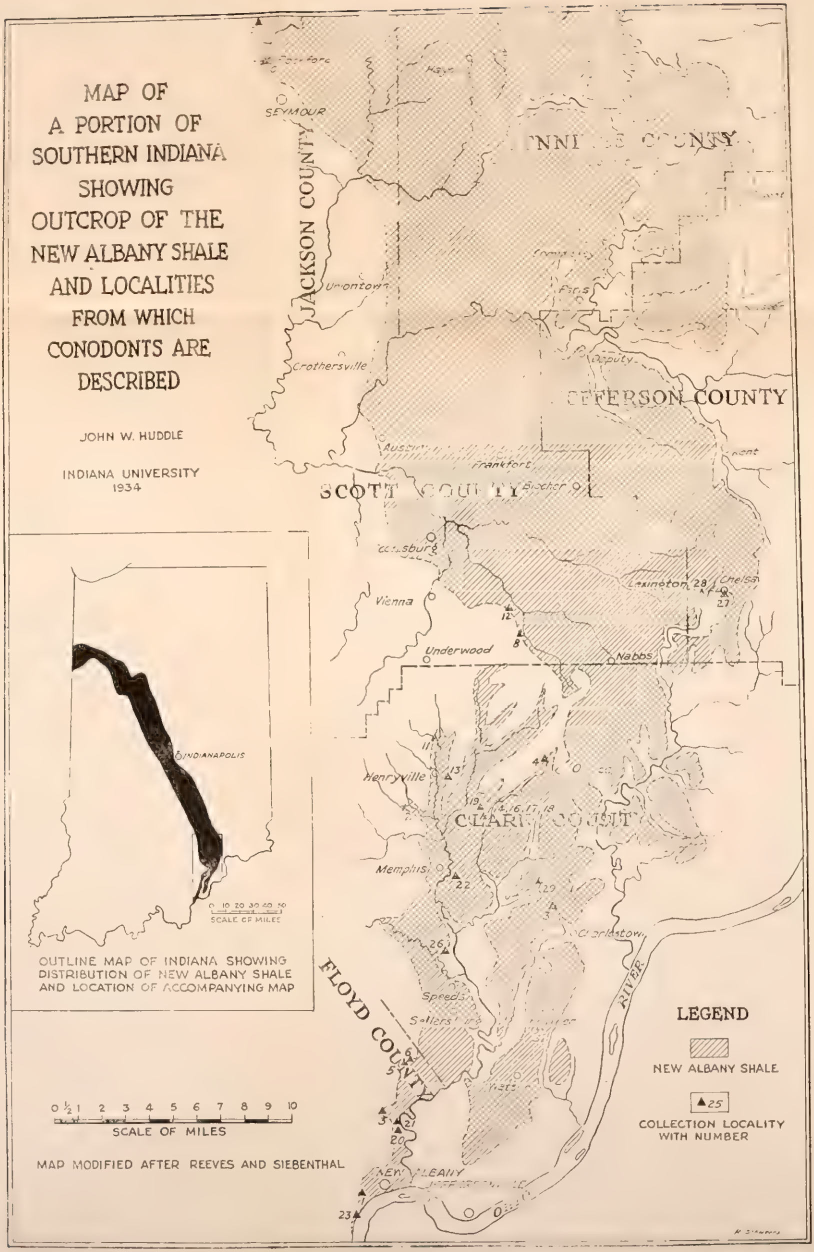
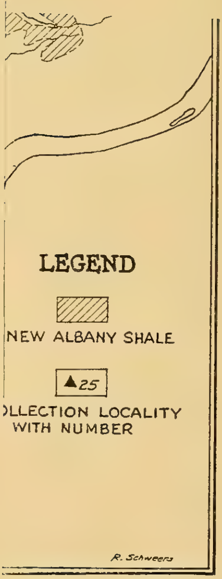

MAP OF A PORTION OF SOUTHERN INDIANA SHOWING OUTCROP OF THE NEW ALBANY SHALE AND LOCALITIES FROM WHICH CONODONTS ARE DESCRIBED
JOHN W. HUDDLE
INDIANA UNIVERSITY 1934
OUTLINE MAP OF INDIANA SHOWING DISTRIBUTION OF NEW ALBANY SHALE AND LOCATION OF ACCOMPANYING MAP
INDIANAPOLIS
0 10 20 30 40 50
SCALE OF MILES
0 ½ 1 2 3 4 5 6 7 8 9 10
SCALE OF MILES
MAP MODIFIED AFTER REEVES AND SIEBENTHAL
SEYMOUR
JACKSON COUNTY
Uniontown
Crothersville
Paris
Deputy
JEFFERSON COUNTY
Frankfort
SCOTT COUNTY
Vienna
Underwood
Lexington
Chelsea
Nabbs
Henryville
CLARK COUNTY
Memphis
Charlestown
Speeds
Sellers
FLOYD COUNTY
RIVER
NEW ALBANY
LEGEND
NEW ALBANY SHALE
▲25
COLLECTION LOCALITY WITH NUMBER

Frontispiece, Figure 1

Map of a portion of Southern Indiana showing the outcrops of the New Albany shale and the localities from which Conodonts are described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BULLETINS

OF

AMERICAN PALEONTOLOGY

Vol. 21

* * *

No. 72

Conodonts from the New Albany Shale of Indiana

By John Warfield Huddle

November 5, 1934

PALÆONTOLOGICAL RESEARCH INSTITUTION
FOUNDED 1932

Ithaca, New York

CONODONTS FROM THE NEW ALBANY SHALE OF INDIANA[1]

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[1] Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Geology in the Graduate School of Indiana University, May, 1934.

INTRODUCTION

The New Albany shale is one of several Devonian-Mississippian black shales whose age and correlation have been in doubt. By most students the New Albany shale has been correlated as Devonian, but Schuchert[2], Ulrich[3], and Bassler[4] have considered it partly Devonian and partly Mississippian.

My interest was first aroused in the problem of the age of the New Albany shale by some invertebrate fossils collected by Prof. C. A. Malott and Mr. W. D. Thornbury from near the top of the formation at a locality about two miles north of Rockford, Indiana. Invertebrate fossils had never before been found at this horizon and because of their bearing on the age of the New Albany they were given to me for description and publication[5]. During the study of the invertebrate fossils, conodonts were discovered by Prof. Cumings and myself in the black shale just above the zone containing the other fossils. The outcome of this discovery is the present paper. It was hoped, when the work was started, that the study of the conodonts would lead to a definite age determination and correlation of the upper part of the New Albany shale. It was also expected that if the upper part was found to be Mississippian and the lower part Devonian a careful zoning of collections would enable a determination of the thickness of shale above and below the disconformity. With these objects in view collecting was largely limited to localities where the horizon could be definitely determined, and more collecting was done in the middle and upper part of the formation than in the lower part whose age was definitely known to be Devonian.

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[2] Schuchert, Charles. 1910. Paleogeography of North America. Bull. Geol. Soc. Amer., vol. 20, p. 548.

[3] Ulrich, E. O., 1911. Revision of the Paleozoic Systems. Bull. Geol. Soc. Amer., vol. 22, pl. 29, p. 608.

[4] Bassler, R. S., 1912. The Waverlyan Period of Tennessee. Proc. U. S. Nat. Mus., vol. 41, p. 223.

[5] Huddle, J. W., 1933. Marine fossils from the top of the New Albany shale of Indiana. Amer. Jour. Sci., vol. 25, pp. 303-314.

Field work was carried on during the summers of 1932 and 1933 through the financial aid of the Indiana State Department of Conservation, Division of Geology. In the fall of 1933 a short field trip was made to the Central Basin of Tennessee to secure conodonts from the Hardin and Chattanooga formations for comparison.

ACKNOWLEDGMENTS

I wish to make grateful acknowledgment to everyone who has aided in the completion of this research: especially to Prof. E. R. Cumings and Prof. J. J. Galloway for directing the research and reading the manuscript; to Mr. C. L. Cooper for criticism and suggestions; to Mr. W. L. Bryant for the identification of *Cladodus springeri;* to Dr. G. I. Whitlatch for field assistance and specimens for comparison; to Dr. H. H. Bradfield and Mr. R. V. Hollingsworth for material for comparison; and to Miss Frances Beede and Miss Mary Alice Huddle for some of the drawings.

STRATIGRAPHY

Name.—According to Cumings[6], 1926, the name New Albany was proposed by Borden, in 1874, for the "black slate" or "black lingula slate". It includes the shale lying between the Middle Devonian limestones and the Rockford formation (Kinderhookian), or New Providence shale where the Rockford is absent, in Indiana and Kentucky, and has its type region at New Albany, Indiana. Cumings[7] has made an excellent resume of the history of the names applied and the correlations made, and this information need not be repeated here.

Outcrop area.—The outcrop area of the New Albany shale in Indiana is divided into a northern and southern area by the glacial drift cover. The southern area extends from the Ohio River in a northerly direction to Johnson County. Many sections are available in Clark, Floyd, Scott, and Jennings counties, and these counties are the best places in which to study the formation. A few sections showing the base of the formation are available in Jefferson county, and the outcrops in Jackson, Bartholonew, and Johnson counties are scattered and generally much weathered.

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[6] Cumings, E. R., 1922. Handbook of Indiana Geology, pt. 4, Nomenclature and description of the geological formations of Indiana. Indiana Dept. of Conservation, Div. of Geology, publication no. 21, p. 472.

[7] Op. cit., 472-475.

North of Johnson County the New Albany is covered by glacial drift except in the northern area of outcrop where the Wabash and its tributaries have removed the drift. Outcrops in this latter area are chiefly limited to Carroll and White counties, and most of them are much weathered and offer little opportunity for collecting conodonts. No identifiable specimens of conodonts have been found in northern Indiana.

Physiographically the southern outcrop area lies in the Scottsburg Lowland, and the lower part of the New Albany shale extends eastward on to the Muscatatuck regional slope.

Thickness.—The thickness of the New Albany shale varies from about 80 feet to 145 feet, averaging about 100 feet. According to Reeves[8] the formation is 104 feet thick at New Albany, Indiana, and 147 feet at Brownstown, Indiana. The entire thickness is not exposed in any one outcrop, and most of the information about total thickness is obtained from well logs. At some localities in Clark and Floyd counties as much as 70 feet of shale is exposed, and at places the top and bottom of the formation are separated by a horizontal distance of less than two miles.

Lithology.—Fresh New Albany shale is brownish to black in color, more or less massive, hard, brittle, and breaks with a conchoidal fracture. With weathering the color changes from black to light brown or gray and finally to the poor, light yellow clay soil so characteristic of Scott County. Weathering also develops fissility and the characteristic splitting into thin sheets gives the reason for the local name of "black slate". Some layers, however, never become fissile, especially the more massive layers with some calcium carbonate. Pyrite occurs throughout the shale.

Jointing in two directings is characteristic of the formation, and some of these joints extend through as much as 70 feet of shale. The perfect jointing permits the shale to be wedged out in large rectangular blocks. In Clark and Floyd counties the joints run approximately north-south and east-west.

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[8] Reeves, J. R., 1922. Handbook of Indiana Geology, pt. 6, Preliminary report on the oil shales of Indiana. Indiana Dept. of Conservation, Div. of Geology, publication no. 21, pp. 1068, 1075.

In general the lithology of the New Albany shale is remarkably consistent, but locally the black shale is replaced by lenses of gray shales, sandstones, or sandy limestones. The gray shales are usually very thin, but at some places reach a thickness of several feet. At only one locality has gray shale been found within 20 feet of the top. This is the locality about 2 miles north of Rockford, Indiana, where the brachiopods were collected. Here the gray-green shale is at least 18 inches thick and the base is not exposed. Elrod[9], in 1881, reported a fossiliferous gray-green shale, which he regarded as equivalent to the Rockford, at "Catfish Falls" of White River northwest of Columbus, Indiana. The Rockford occurs as a limestone in this vicinity and the gray-green shale mentioned by Elrod may be in the upper part of the New Albany shale and be equivalent to the shale found north of Rockford, Indiana. The exact locality of "Catfish Falls" has not been determined, and I have been unable to find the shale, described by Elrod, at any of the falls of White River northwest of Columbus, Indiana, possibly due to high water at the times the outcrops were visited.

In the vicinity of New Albany several outcrops show thin gray shales. At Armstrong Bend of Silver Creek east of New Albany, Indiana, there are three 6 inch beds of gray shale separated by about a foot of black shale, and overlain by 50 feet of black shale. Three similar beds of gray shale are exposed in the road cut at the junction of Mt. Tabor road and U. S. Highway 31-W, north of New Albany, Indiana, but these gray shales are not more than 30 feet below the Rockford, and therefore cannot be the same as those at Armstrong Bend.

The sandstones and limestones found in the New Albany are thin, usually an inch or less in thickness. They are more common in the lower 15 feet of the formation but are also found in the upper part and are not found at all localities at the same horizon. Often the sandstones and limestones occur as thin rectangular joint blocks on weathered outcrops. Some of the sandstones and limestones contain conodonts.

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[9] Elrod, M. L., 1881. Geology of Bartholomew County. Indiana Geology and Nat. Hist., 11th ann. rept., p. 198.

At the base of the New Albany shale in Indiana there are a few inches of limestone, sandstone, conglomerate, pyrite, or red clay at many localities as at Speed, Charlestown, Chelsa, and Lexington.

The following geological sections are included in order to show some of the lithologic variations:

Section in the S. E. 1/4, Grant 223, in the road cut on the Charlestown-Henryville road and gully east of the road, about 3 miles southeast of Henryville, Clark County, Indiana.

	Ft.	In.
New Providence shale		
Rockford formation		
Massive, hard gray, mottled green, brown weathering limestone	1	
Gray-green shale	1	
New Albany shale		
Black fissile shale	1	
Zone of small concretions		3-6
Black fissile shale	12	
Dark brown limestone with pyrite		1
Black fissile shale	2	
Dark brown limestone with pyrite		½
Black fissile shale	5	
Brown weathering sandstone		½
Black fissile shale	17	
Three thin gray-green shales separated by about a foot of black fissile shale	4	
Black fissile shale to creek level	15	

Section 1½ miles east of Hayden, 5 miles west of North Vernon on U. S. Highway 50, where the highway crosses a tributary of Six Mile Creek. There is a R. R. bridge a short distance north of the road. Section in road cut.

	Ft.	In.
New Albany shale		
Gray weathered shale	3	
Black fissile shale with large blue-gray lime concretion	5	
Covered	5	
Section in the creek bank and downstream to Six Mile Creek		
Black fissile shale	15	
Brown, laminated sandstone		½
Black fissile shale		2
Dark brown limestone breaking into rectangular blocks		1
Black fissile shale		1
Gray shale	10	
Gray shale with black specks, somewhat weathered	10	
Covered	5	
Brown weathering, gray sandstone with pyrite. Conodonts		6
Black fissile shale	5	
Zone of large, dark brown concretions		
Black fissile shale	10	
Middle Devonian, light gray limestone exposed in bed of Six Mile Creek.		

The section was measured by barometer and hand level, because the gradient of the creek is low and hand level measurements are not feasible for the whole section. Barometer measurements are not exact, but the section is included because of the unusually thick gray shales, and because of other lithologic variations. The conodont bearing sandstone outcrops about 150 yards downstream from the railroad bridge.

Other sections showing lithologic variations could be given and some have been published by Kindle[10], Reeves[11] and others.

Concretions.--At least three zones of concretions occur in the New Albany shale. Near the top of the formation, from one to four feet below the Rockford formation, there is a consistent zone of small concretions from one to three inches in diameter. The zone is easily recognized and occurs in nearly every outcrop of the top of the New Albany in southern Indiana. No other zones of small concretions have been found.

Large, elliptical, lime concretions from one to three feet in diameter are found at two or more horizons. They are dark brown or light blue-gray in color with more or less pyrite, sometimes containing conodonts and small black conical teeth. The horizon of these concretions has not been definitely determined, because at most of the localities where they occur neither the base nor the top of the formation is exposed. Where the horizon has been determined in relation to the top of the formation, the upper zone of large concretions is found between 40 and 50 feet below the Rockford formation. In the section east of Hayden, given above, the lower zone is found about 10 feet above the base, and the middle zone 64 feet above the base. At North Vernon the lower zone occurs 3 feet above the base. It is possible that large concretions occur throughout the lower 70 feet of the New Albany shale, but it is more probable that they are limited to the two horizons.

The shale surrounding both the large and small concretions is considerably warped, and Reeves[12] considered the warping as evidence of the force exerted by their growth. Some of the warping may be due to compaction of the shale around the concretions. The cleavage of the shale around the concretions does not seem to be parallel to bedding planes. The shale around pyrite nodules is similarly warped.

[10] Kindle, E. M., 1901. Devonian fossils and stratigraphy of Indiana. Indiana Dept. of Geology and Nat. Resources, 25th ann. Rept., pp. 532-570.

[11] Reeves, J. R., 1922. Handbook of Indiana Geology, pt. 6, Preliminary report of the oil shales of Indiana. Indiana Dept. of Conservation, Div. of Geol., publication no. 21, pp. 1079-1089.

[12] Op. cit. p. 1070.

Relation to underlying formations.—The New Albany shale rests unconformably on Middle Devonian limestones in Indiana. In Clark and Floyd counties it usually rests on the Beechwood limestone, but occasionally the Beechwood is absent and the New Albany rests on the Silver Creek limestone. In Scott and Jefferson counties the New Albany overlies the Silver Creek limestone at most localities, but at a few places the Beechwood limestone may be present, as in the road cut about a mile north of Lexington, Indiana. In Jennings County the Silver Creek lithology has disappeared and the *Spirifer acuminatus* and *Spirifer oweni* faunas are found in a white crystalline limestone similar to the rock including the *Spirifer acuminatus* zone in the Jeffersonville limestone. At some localities in Jennings County the New Albany rests on this limestone, but at the North Vernon quarry and a few other localities in the vicinity of North Vernon the New Albany lies unconformably on a blue crinoidal limestone that may be equivalent to the Beechwood. The section of Devonian limestone is unusually thick in Jennings County and the stratigraphy is not completely worked out. In northern Indiana the New Albany rests on an unnamed middle Devonian limestone, whose stratigraphy is as little understood as the Jennings County Devonian. Kindle[13] recognized Sellersburg (Silver Creek and Beechwood) and Jeffersonville limestone in northern Indiana, but stated that the fauna of the "Sellersburg" was entirely different from the Sellersburg of southern Indiana. The "Sellersburg" of northern Indiana may represent much the same time interval as the Silver Creek and Beechwood of southern Indiana, but it is not the same formation and needs a distinct name.

There is no great overlap of the New Albany shale in Indiana as there is in Kentucky where, according to Savage[14], the New Albany overlaps Silurian and Ordovician formations. Faunally the break is distinct, from Hamilton (Silver Creek and Beechwood) and Onondaga (Jeffersonville) to Tully in Kentucky, and to Genesee in Indiana.

Relation to the overlying formation.—In Indiana the New Al-

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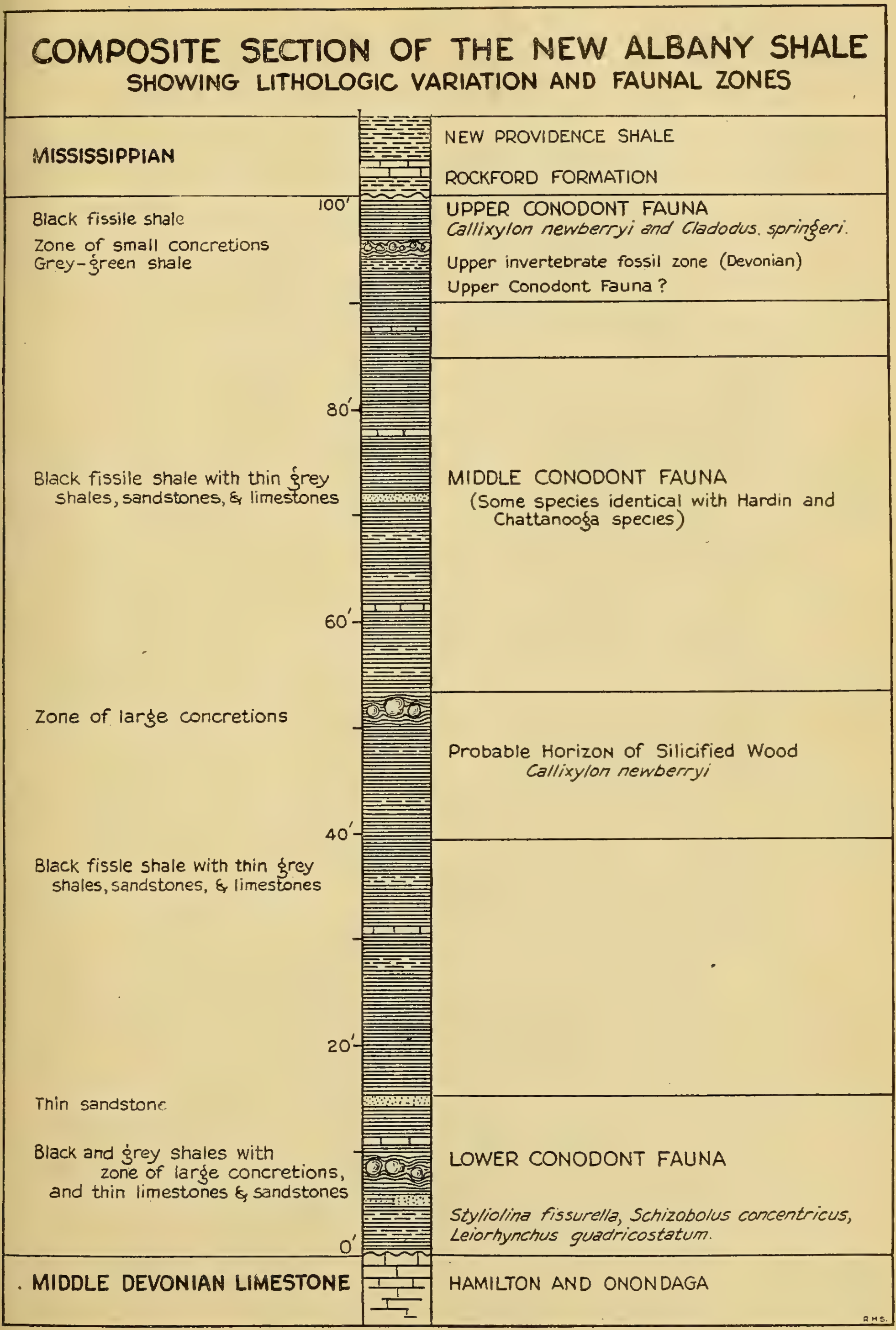
[13] Op. cit. pp. 561-562.

[14] Savage, T. E. 1930. Devonian rocks of Kentucky. Ky. Geol. Surv., series 6, vol. 33, pp. 20-21.

Figure 2


COMPOSITE SECTION OF THE NEW ALBANY SHALE
SHOWING LITHOLOGIC VARIATION AND FAUNAL ZONES
MISSISSIPPIAN
NEW PROVIDENCE SHALE
ROCKFORD FORMATION
100′
Black fissile shale
Zone of small concretions
Grey-green shale
UPPER CONODONT FAUNA
Callixylon newberryi and Cladodus. springeri.
Upper invertebrate fossil zone (Devonian)
Upper Conodont Fauna ?
80′
Black fissile shale with thin grey shales, sandstones, & limestones
MIDDLE CONODONT FAUNA
(Some species identical with Hardin and Chattanooga species)
60′
Zone of large concretions
Probable Horizon of Silicified Wood
Callixylon newberryi
40′
Black fissle shale with thin grey shales, sandstones, & limestones
20′
Thin sandstone
Black and grey shales with zone of large concretions, and thin limestones & sandstones
LOWER CONODONT FAUNA
Styliolina fissurella, Schizobolus concentricus, Leiorhynchus quadricostatum.
0′
MIDDLE DEVONIAN LIMESTONE
HAMILTON AND ONONDAGA
R H S.

bany shale is unconformably overlain by the Rockford formation. In Kentucky, however, the Rockford is absent according to Kindle[15], Butts[16], and others, and the New Providence shale of the Borden Group (Mississippian) rests directly on the New Albany shale.

The Rockford formation consists of a massive, dense, gray, green mottled limestone and an underlying gray-green shale. The formation outcrops at many localities in southern Indiana, and has been recognized by Shrock and Malott[17] in northern Indiana at a locality near Goodland. In thickness the limestone varies from 1 to 4½ feet, and the gray-green shale is usually less than a foot thick, but is probably present at all localities although at many places the limestone has slumped and obscured the shale.

No great amount of New Albany shale was removed before the deposition of the Rockford formation in southern Indiana, as is shown by the consistent presence of the conodonts and *Lingula* just above the zone of small concretions, within 5 feet of the top.

Occurrence of conodonts in the New Albany shale.—Conodonts have been found in the New Albany shale of southern Indiana at three horizons (see fig. 2); an upper horizon 0 to 10 feet below the Rockford formation; a middle horizon 15 to 50 feet below the Rockford formation; and a lower horizon 0 to 15 feet above the base. Collecting has been largely limited to localities where the horizon could be determined, and more collecting has been done at the middle and upper horizons than at the lower. This was because of the stratigraphic emphasis placed on the work. Additional collections may yield conodonts from the interval between the lower and middle horizons, but this part of the section does not offer numerous relatively fresh outcrops as does the upper half of the formation.

The largest number of species and specimens was found at the upper horizon. Specimens are particularly abundant just above a layer of small concretions, which occurs 1 to 5 feet below the top of the New Albany shale at nearly every locality in southern Indiana. In some layers conodonts occur in such profusion that the surfaces of the slabs are roughened, but the majority of the specimens are broken. *Lingula, Orbiculoidea,* "dermal plates," and small black conical teeth are associated with the conodonts at this horizon.

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[15] Kindle, E. M., 1899. Devonian and Lower Carboniferous faunas in southern Indiana and central Kentucky. Amer. Paleo., Bull. 12, 111 pp.

[16] Butts, Charles, 1915. Geology and mineral resources of Jefferson County, Kentucky. Ky. Geol. Surv., ser. 4, vol. 3, pt. 2, p. 136.

[17] Shrock, R. R., and Malott, C. A., 1930. Notes on some northwestern Indiana rock exposures. Proc. Ind. Acad. Sci. for 1929, vol. 39, p. 223.

Conodonts are rarer both in number of species and specimens at the middle horizon. They occur sparingly from 15 to 50 feet below the top of the formation, not, however, throughout the zone but at several horizons, usually a few inches thick. The shale in this part of the section is frequently more massive, and the lack of fissility and consequent greater difficulty in collecting may partially account for the fewer number of specimens.

At the lower horizon conodonts are not abundant and have been found at only a few locations. Ordinarily they do not occur with *Styliolina fissurella;* a few have been found with this fossil and it may be that its abundance obscures the conodonts. The majority of conodonts have been collected from the lower two feet of the formation and have not been found higher than 15 feet above the base. At Locality 26, north of Speed, Indiana, (see fig. 1) most of the conodonts occur in the basal limestone conglomerate and sparingly in the shale above. At Locality 33, near Hayden, Indiana, the conodonts are found in a sandstone 15 feet above the base. Not only are conodonts found at few localities at the lower horizon, but also the number of fresh outcrops is limited, and consequently the material available is not as satisfactory as that from the middle and upper horizons.

The extreme abundance of conodonts in small layers, and their almost total absence above and below is very striking in the New Albany shale. It would appear that the horizons of extreme abundance represent either a catastrophe or periods of slight or non-deposition. Sometimes fragments of conodonts, conical black teeth, "dermal plates" and fragments of *Lingula* occur in small, round or ovate patches, and apparently represent the ejectamenta of some fish. The shale in these patches is usually lighter in color than the surrounding shale. They certainly are not the remains of a single individual since they contain a heterogeneous assortment of conodonts and other organisms.

The conodonts of the New Albany shale are best studied in the shale. They are fractured and if removed from the shale fall into several pieces. Careful work with a fine needle is necessary to uncover portions of most specimens. Some of the massive species of *Polygnathus, Spathodus,* and *Bryantodus* have been removed from the shale in one piece by careful digging with a needle, but even these rarely come out whole, and in general removal is impracticable. Boiling produces almost no effect on the shale. Some of the conodont-bearing basal limestone from Speed, Indiana, has been crushed but only small fragments survived. Crushing of the sandstone from Hayden, Indiana, produced better results, but even here only the small species of the Polygnathidae survived whole and the appearance of the fauna was completely changed, because the more delicate specimens were fragmented beyond recognition.

If the specimens are free and one can see both sides, study is greatly facilitated and many errors are eliminated. The recognition of the opposite sides of the same species is sometimes extremely difficult, and fragments and molds are confusing. Fragments are not always easily recognized as such, and many large fragments can not be identified generally. The use of molds is unsatisfactory, because, if the specimen lies in the shale at an angle, splitting may cut off and foreshorten the cusp and denticles and leave them pointed. Under such conditions there is no way of telling the true proportions.

Since the recognition of the denticles on the anticusp of *Ligonodina* by Cooper and Branson and Mehl, all similar conodonts must be carefully dug out in search for such structures, and to be sure that the entire specimen is uncovered. The angle at which the specimen lies in the shale greatly affects its appearance.

FAUNAL CHART

	New Albany shale			Rhinestreet sh., and Middlesex sh. (Portage) New York	Genundewah ls. (Genesee) New York	Hardin ss. Mt. Pleasant, Tenn.	Chattanooga sh. Huntsville, Ala.	Woodford fm. Oklahoma	Welden sh. Oklahoma
	Lower	Middle	Upper						
Prioniodus alatus Hinde	x		x	x	x				
P. alatoideus Cooper		x	x					x	
P. macrocornatus Cooper		x						x	
Hindeodella priodon, n. sp.	x								
H. species	x								
H. catacta, n. sp.			x						
H. aculeata, n. sp.		x	x						
H. grandis, n. sp.			x						
H. species			x						
H. compressa, n. sp.			x						
H. elongata, n. sp.			x						
H. species			x						
H. laticlavis, n. sp.			x						
H. gracilis, n. sp.	x								
H. alternidens, n. sp.			x						
H. angulus, n. sp.	x								
H. deflecta Hibbard		x	x	x					
H. emacerata, n. sp.			x						
H. panderi Hibbard			x	x					
H. tenerrima Holmes?			x				x		
H. species		x							
H. jubata, n. sp.		x							
H. conidens, n. sp.			x						
Hamulosodina? perangulata n. sp.			x						
H. species			x						
Hindeodelloides bicristatus, n. sp.	x	x	x						
H. alatus, n. sp.		x							
H. minutus, n. sp.		x							
H. species		x							
H. ? species		x							
H. species			x						
H. gracilis, n. sp.			x						
Euprioniodina species	x								
E. fornicata, n. sp.		x	x						
E. prona, n. sp.			x						
E. devexa, n. sp.		x							
E. perangulata U. & B.	x			x					
E. debilis, n. sp.	x								
E. falx, n. sp.	x								

FAUNAL CHART

(CONTINUED)

	New Albany shale			Rhinestreet sh. (Portage) New York	Genundewah ls. (Genesee) New York	Hardin ss. Mt. Pleasant, Tenn.	Chattanooga sh. Huntsville, Ala.	Woodford fm. Oklahoma	Welden sh. Oklahoma
	Lower	Middle	Upper						
Synprioniodina plana Holmes			x			x			
S. newalbanyensis, n. sp.			x						
S. acilis, n. sp.			x						
S. decurrens, n. sp.		x	x						
Palmatodella delicatula U. & B.		x				x	x	x	
P. ? paridens, n. sp.			x						
Metaprioniodus biangulatus, n. sp.			x						
M. fracta, n. sp.			x						
Ligonodina species			x						
L. species			x						
L. hindei U. & B.	x			x					
L. pinguis (Hibbard) ?			x	x					
L. species			x						
L. species			x						
L. species			x						
L. bicincta, n. sp.		x							
L. cryptodens, n. sp.	x								
L. conidens, n. sp.			x						
L. arcuata, n. sp.	x								
Prioniodina separans Holmes			x				x		
P. acicularis, n. sp.			x						
P. curta, n. sp.	x								
P. arrecta, n. sp.		x							
P. subrecta, n. sp.			x						
P. cunea, n. sp.			x						
P. ordinata, n. sp.		x							
P. cristula, n. sp.		x							
Bryantodus cognatus, n. sp.		x							
B. multidens U. & B.	x			x					
B. pergracilis U. & B.			x			x			
B. subbrevis U. & B.			x			x			
B. camurus, n. sp.			x						
B. microdens, n. sp.			x						
B. pectenellus, n. sp.	x								
B. flexus, n. sp.	x								
B. commutatus, n. sp.	x								
B. concavus, n. sp.	x								
B. serrula, n. sp.			x						
B. plenus, n. sp.		x							
B. brevidens, n. sp.			x						
B. cf. germanus Holmes			x				x		
B. coalescenoides, n. sp.	x								
B. notatus, n. sp.		x							
B. incisus, n. sp.	x								
B. subplanus, n. sp.		x							
B. subcarinatus, n. sp.		x							
B. parvus, n. sp.		x	x						
B. mirus, n. sp.		x							
B. nodus, n. sp.			x						

FAUNAL CHART

(CONTINUED)

	New Albany shale			Rhinestreet sh. (Portage) New York	Genundewah ls. (Genesee) New York	Hardin ss. Mt. Pleasant, Tenn.	Chattanooga sh. Huntsville, Ala.	Woodford fm. Oklahoma	Welden sh. Oklahoma
	Lower	Middle	Upper						
B. planus, n. sp.			x						
B. aplatus, n. sp.	x								
Angulodus demissus, n. sp.	x								
A. gravis, n. sp.		x							
A. walrathi (Hibbard)			x	x					
A. spissus, n. sp.		x							
Hibbardella angulata (Hinde)	x	x	x	x	x				
H. symmetrica, n. sp.			x						
H. ? telum, n. sp.	x	x	x						
H. pandata, n. sp.	x								
H. distans, n. sp.		x							
H. insignis, n. sp.			x						
H. ? divergens, n. sp.			x						
Lonchodina cf. extenta Hibbard			x	x					
L. nitela, n. sp.	x								
L. ? erecta, n. sp.		x							
L. multidens Hibbard	x			x					
L. species			x						
L. ? projecta U. & B.	x		x	x					
L. species			x						
L. distans, n. sp.			x						
L. acutula, n. sp.	x								
L. tenuis, n. sp.	x								
L. bicornis, n. sp.			x						
L. torta, n. sp.			x						
L. prava, n. sp.		x							
L. subsymmetrica U. & B.		x		x					
Falcodus angulus, n. sp.		x	x						
F. tortus, n. sp.			x						
F. species			x						
F. conflexus, n. sp.			x						
F. ? granulosus, n. sp.			x						
Spathodus strigilis, n. sp.	x		x						
S. parvus, n. sp.			x						
S. subrectus, (Holmes)		x	x				x		
S. duplidens, n. sp.			x						
S. rectus (Holmes)			x				x		
Polygnathellus similis, n. sp.			x						
Gondolella ? nodosa, n. sp.	x								
Polygnathus lacinata, n. sp.			x						
P. linguliformis Hinde	x				x				
P. pennata Hinde	x				x				
P. peracuta Bryant	x				x				
P. bryanti, n. sp.	x				x				
P. signata, n. sp.	x								
P. rugosa, n. sp.	x								
P. foliata, Bryant	x				x				

FAUNAL CHART

(Concluded)

	New Albany shale			Rhinestreet sh. (Portage) New York	Genundewah ls. (Genesee) New York	Hardin ss. Mt. Pleasant, Tenn.	Chattanooga sh. Huntsville, Ala.	Woodford fm. Oklahoma	Welden sh. Oklahoma
	Lower	Middle	Upper						
P. rhomboidea U. & B. ?		x					x		
P. alata, n. sp.	x								
P. rimulata U. & B.	x			x					
P. sulcata, n. sp.			x						
P. newalbanyensis, n. sp.			x						x
P. caelata Bryant	x				x				
P. scapha, n. sp.			x						
P. rotundiloba Bryant	x				x				
P. ectypa, n. sp.	x								
P. plana, n. sp.			x						
P. similis, n. sp.		x							
P. aspera, n. sp.	x								
P. species		x							
P. concentrica U. & B.		x				x	x		
P. gyratilineata Holmes		x				x			
Palmatolepis pustulosa, n. sp.		x							
P. species	x								
P. cymbula, n. sp.		x							
P. pectenifera, n. sp.		x							
P. elongata Holmes		x					x		
P. ? inequalis Holmes		x					x		
P. perlobata U. & B.		x				x	x		
P. minuta, n. sp.			x						

Age and correlation of the New Albany shale.—The Genesee age of the lower part of the New Albany shale in Indiana has not been questioned in recent years. In Kentucky, however, Savage[18] has shown, by finding *Hypothyrodina cuboides* and other fossils in the Duffin layer at the base of the New Albany, that deposition began in Tully time, and because of the occurrence of Genesee fossils higher in the New Albany he believed that deposition was continuous from Tully to Genesee. Kindle[19] considered the presence of *Spathiocaris emersoni* as evidence that deposition continued into Portage time in Indiana.

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[18] Savage, T. E., 1930. Devonian rocks of Kentucky. Ky. Geol. Surv., ser. 6, vol. 33, pp. 17, 79, 142.

[19] Kindle, E. M., 1901. Devonian fossils and stratigraphy of Indiana. Ind. Dept. Geol. and Nat. Resources, 25th ann, rept. for 1900, pp. 569-570.

Since Schuchert[20], 1910, Ulrich[21], 1911, and Bassler[22], 1912, regarded the upper part of the New Albany shale as Mississippian, there has been some question as to its age. According to Butts[23], 1915, Ulrich considers the upper 85 to 90 feet of the New Albany shale as Mississippian; Butts, however, was not inclined to favor this view and considered the New Albany as Devonian, as have Cumings[24], 1922, Savage[25], 1930, and others.

According to Swartz[26], the Chattanooga shale of eastern Tennessee and western Virginia may be divided into three members: a lower black shale, the Cumberland Gap; a middle gray shale, the Olinger; and upper black shale, the Big Stone Gap. The Olinger member contains a Mississippian fauna, and interfingers with the upper part of the Cumberland Gap member. The largest part of the Chattanooga shale is therefore Mississippian, and the lower part of the Cumberland Gap member is the only part of the Chattanooga of this region that may be Devonian. The relationship of the Chattanooga shale in the Central Basin of Tennessee to the three members named by Swartz is not certain. Ulrich and Bassler[27], 1926, found that none of the New York Genesee and Portage species of conodonts was identical with species from equally large faunas from the Ohio shale, the New Albany shale, or the Chattanooga shale. They regarded this as conclusive evidence of the Post-Devonian age of these formations. Bassler[28], 1932, adds that many of the Hardin and Chattanooga species are identical with species from the "Mississippian shale, of northern Ohio." If this statement is correct, it is an indication of Mississippian age for the Chattanooga shale of the Central Basin of Tennessee, but it is not conclusive until the evidence for the statement has been presented. Bassler[29] further states of the Chattanooga shale, "In its western extension it maintains its character of a thin shale of Mississippian age, but in the northern states it overlaps older black shales, which combined with it in Indiana and Kentucky are known as the New Albany shale and in Ohio as the Ohio shale"; thus reaffirming his belief that the upper part of the New Albany shale is Mississippian and correlatable with the Chattanooga.

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[20] Schuchert, Charles, 1910. Paleogeography of North America. Bull. Geol. Soc. Amer., vol. 20, p. 548.

[21] Ulrich, E. O., 1911. Revision of the Paleozoic Systems. Bull. Geol. Soc. Amer., vol. 22, pl. 29, p. 608.

[22] Bassler, R. S., 1912. Waverlyan Period in Tennessee. Proc. U. S. Nat. Mus., vol. 41, p. 223.

[23] Butts, Charles, 1915. Geology and mineral resources of Jefferson County, Kentucky. Ky. Geol. Surv., ser. 4, vol. 3, pt. 2, pp. 133-134.

[24] Cumings, E. R., 1933. Handbook of Indiana Geology, pt. 4, Nomenclature and descriptions of the geological formations of Indiana. Ind. Dept. of Conservation, Div. of Geology, publication no. 21, p. 474.

[25] Op. cit., pp. 18-19.

[26] Swartz, J. H., 1929. Age and stratigraphy of the Chattanooga shale. Amer. Jour. of Sci., vol. 17, pp. 431-448. (see also earlier papers)

[27] Ulrich, E. O., and Bassler, R. S., 1926. A classification of the toothlike fossils, conodonts, with descriptions of American Devonian and Mississippian species. Proc. U. S. Nat. Mus., vol. 68, p. 3.

[28] Bassler, R. S., 1932. Stratigraphy of the Central Basin of Tennessee. Tenn. Div. of Geol., bull. 38, p. 137.

Pohl[30], 1930, divided the Chattanooga shale of the Central Basin of Tennessee into three units, all separated by unconformities. The upper and middle units he considered as Mississippian and correlated them with the Sunbury and Cleveland shales respectively (the Mississippian age of the Cleveland is disputed); the lower unit he named Trousdale and correlated it with the Genesee-Portage black shales of the northeastern Devonian. He considered the Mississippian (upper and middle units) as widespread, and the Devonian Trousdale as only locally developed. Savage and Sutton[31], 1931, proved the presence of a Mississippian black shale in Allen County, Kentucky, by finding a Mississippian fauna in the upper part of the black shale of this region. They, however, unlike Pohl, regard this Mississippian phase as only local and the Devonian phase as widespread in south-central Kentucky and north-central Tenessee.

Fossil wood offers evidence of probable Devonian age of the New Albany shale above the calcareous sandstone zone 10 to 15 feet above the base of the formation (not present at all localities) regarded by Ulrich as the base of the Mississippian. Loose pieces of silicified wood have been found as high as 50 feet above the base of the formation, and Dr. G. G. Bartle[32] has identified some of these specimens as *Callixylon newberryi*, a Devonian species. Reeves[33] reported that he found a log in the shale at the Bridgewater quarry 2½ miles east of Vienna, Indiana. The horizon at this quarry is near the middle of the formation. . The horizon of the silicifed wood seems to be near the middle of the formation, and it is certainly higher than 15 feet above the base. According to Arnold[34], the "jointed" carbonized plant remains found in the Antrim, New Albany, and Ohio shales called *Calamites inornatus* or *Pseudobornia* are fragments of *Callixylon newberryi.* These carbonized fragments have been found as high as 6 feet below the top of the New Albany shale at Locality 14, southeast of Henryville, Indiana, and they offer evidence of probable Devonian age of the formation up to this horizon. Associated with these specimens are conodonts of the upper conodont fauna. Arnold[35], 1931, also reports some pieces of silicified wood in place in the New Albany shale of southern Indiana, and since *Callixylon* is not known from the Mississippian, he regards *Callixylon newberryi* as probably Devonian[36], but admits the possibility of an early Mississippian age. However, since *Callixylon newberryi* occurs in the Antrim, New Albany, Ohio, and Chattanooga shales, he correlates these formations.

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[29] Op. cit., p. 137.

[30] Pohl. E. R., 1930. Black shales of Central Tennessee. Amer. Jour. Sci., vol. 20, pp. 151-152.

[31] Savage, T. E., and Sutton, A. H., 1931. Age of the black shales in south-central Kentucky. Amer. Jour. Sci., vol. 22, pp. 441-448.

[32] Personal communication.

Additional evidence of the Devonian age of the major portion of the New Albany shale is offered by the Devonian brachiopods found about 5 feet below the top of the formation at a locality about 2 miles north of Rockford, Indiana. At this horizon occur the following species: *Rhipidomella vanuxemi newalbaneosis, Chonetes yandellanus seymourensis, Camarotoechia eximia, Platyrachella* cf. *macbridei, Delthyris* sp., *Orthothetes?* sp., *Platyceras* sp.[37]. These species are without doubt Devonian, and with the evidence of *Callixylon newberryi* prove the Devonian age of the New Albany shale up to 5-10 feet below the top of the formation. Associated with the upper conodont fauna, and occuring above the other invertebrate fossils at the Rockford locality, are species of *Lingula* and *Orbiculoidea* identified with *Lingula otheri,* Devonian, Parkhead of Maryland, and *Orbiculoidea lodiensis media,* also Devonian.

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[33] Reeves, J. R., 1923. Oil shales of Indiana. Dept. of Geol. Indiana University. Mineographed, p. 23.

[34] Arnold, C. A., 1931. On **Callixylon newberryi** (Dn) Elkins and Weiland. Contr. Mus. Paleon. Univ. Mich., vol. 3, no. 12, pp. 207-232. 1934, The so-called branch impressions of **Callixylon newberryi** (Dn) Elkins and Weiland and the conditions of their preservation. Jour. of Geol., vol. 42, pp. 71-76.

[35] Op. cit., p. 210.

[36] Op. cit., p. 228.

[37] Huddle, J. W., 1933, Marine fossils from the top of the New Albany shale of Indiana. Amer. Jour. Sci., vol. 25, p. 305.

The evidence of the age of the New Albany shale offered by conodonts has not been as precise as was hoped when this work was started. This lack of precision is largely due to the fact that most of the species of conodonts in the New Albany shale are new. A total of 158 species, including 18 not identified specifically, have been found in the New Albany shale, and only 37 of these were previously described. With a fauna consisting so largely of new species definite correlations can not be made. Another difficulty lies in the fact that few conodont faunas have been described, and the ranges of conodonts have not been definitely determined. Identifications must be made with species in described faunas, and the presence of a few of these species in a fauna may indicate a true correlation or a false one that would be obvious if another more closely related fauna had been described. There is no doubt that when additional faunas of conodonts have been described definite correlations can be made, and conodonts will be as useful as other types of fossils. It will not be surprising, however, to find some species of conodonts ranging from Late Devonian to Early Mississippian.

The number of species ranging throughout the New Albany shale is small compared to the total number. Three species, namely, *Prioniodus alatus, Lonchodina? projecta,* and *Spathodus strigilis* occur in both the upper and lower conodonts faunas; 3 species, *Hindeodelloides bicristatus, Hibbardella angulata,* and *Hibbardella? telum* occur in the lower, middle and upper faunas; and 8 species occur in the middle and upper faunas. The middle and upper faunas seem to be more closely related than the lower and middle, but if conodonts are found between the lower and middle faunas their relationship may prove to be closer than now known.

The conodont fauna in the lower 15 feet of the New Albany shale contains 46 species, 32 of which are new. Of the 14 previously described species 2 occur in both Genesee (Genundewah limestone) and Portage (Rhinestreet shale), 7 in the Genesee, and 5 in the Portage. One new species *Polygnathus bryanti* also occurs in the Genesee. The conodonts therefore apparently confirm the Genesee correlation for the lower 15 feet of the New Albany shale, up to and including the calcareous sandstone zone regarded by Ulrich as the base of the Mississippian part of the New Albany shale.

The middle conodont fauna contains a total of 47 species, 34 of which are new. Of the 13 previously described species, 8 occur in the Hardin and Chattanooga, 2 in the Portage, 1 in the Genesee, and Portage (*Hibbardella angulata*), and 1 in the Woodford. The occurrence of the Hardin and Chattanooga species is especially interesting in that they occur considerably below the upper brachiopod (Devonian) horizon, (see Fig. 2), and are associated with Portage and Genesee species. The presence of these Hardin and Chattanooga species is not, therefore, undoubted evidence of Mississippian age, and, moreover, the Hardin and Chattanooga of the Central Basin of Tennessee may be of Devonian age.

The upper conodont fauna contains a total of 81 species, 64 of which are new. Of the 17 previously described species 8 occur in the Hardin and Chattanooga, 6 in the Portage, 2 in the Genesee and Portage, and 1 in the Woodford Formation. One new species, *Polygnathus newalbanyensis* occurs also in the Welden, (yellow shale below the Sycamore) in Oklahoma. Associated with *Polygnathus newalbanyensis* in the Welden are *Endothyra baileyi* and other Salem (Mississippian) fossils according to C. L. Cooper[38]. The Genesee and Portage forms occurring in the upper conodont fauna are apparently long ranging forms, but again their occurrence with Hardin and Chattanooga forms is interesting. The extremely large proportion of new species forbids any precise correlation on the basis of these conodonts.

A shark's tooth found associated with the upper conodont fauna at Locality 2, southwest of Henryville, Indiana, was sent to Mr. W. L. Bryant for identification. Mr. Bryant identified the tooth as *Cladodus springeri,* originally described from the Kinderhook. The identification affords some evidence of Mississippian age for the upper few feet of the New Albany shale including the upper conodont fauna, but is not conclusive without supporting evidence.

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[38] Personal communication.

CONCLUSIONS

The occurrence of Genesee invertebrate fossils and conodonts at the base of the New Albany shale indicates that deposition began in Genesee time in Indiana.

Callixylon newberryi and Devonian brachiopods indicate the Devonian age of the New Albany shale up to within 5 or 10 feet of the top.

The upper 5 or 10 feet of the formation, including the upper conodont fauna, afford the only likelihood of a zone of Mississippian age. Most of the conodonts in the upper fauna are new species. The highest previously described Devonian conodonts are from the Portage, (Rhinestreet shale) and there is a thick Devonian section above the Rhinestreet in which a fauna similar to the upper New Albany fauna may yet be found. The fact that the upper conodont fauna probably extends below the upper brachiopod bed and the association with "*Calamites inornatus*" indicates a Devonian age for the whole formation. Conflicting evidence is offered by *Cladodus springeri* (Kinderhookian) found associated with the upper conodonts and by the association of *Polygnathus newalbanyensis* with Salem (Mississippian) fossils in the Welden shale of Oklahoma.

The presence of Hardin and Chattanooga species of conodonts below the upper brachiopod bed in the New Albany shale proves that they are not undoubted evidence of Mississippian age.

When additional conodont faunas from known upper Devonian rocks have been described, more satisfactory correlations of the black shales can be made, and the problem of their age determined.

PALEONTOLOGY

Morphology and the Basis of Classification of Conodonts

The classification of the Distacodidae and the Belodidae is based on the shape of the cusp in cross section, number and character of the denticles on the base, size of the base and the presence or absence of a "pulp cavity." Some of the species described under these two families seem to represent fragments of the cusp and bar of other conodonts, and considerable care must be taken to determine this fact.

The Prioniodidae and Prioniodinidae are divided into genera on the basis of the shape and curvature of the bar, presence or absence of an anticusp and downward deflections, presence or absence of a cusp, and the spacing and amount of fusion of the denticles.

In the Polygnathidae the classification is based on the shape and extent of the plate (on one or both sides of the carina), extent and characteristics of the carina (simple or bifurcating, high denticulated ridge, or low row of nodes, etc.,), presence or absence of a blade, and the type of markings on the oral surface of the plate.

It has seemed advisable to name the "diamond shaped basal expansion" of Ulrich and Bassler, and the "pit" or aboral "cavity" of other authors, and the name *escutcheon* is here proposed. (See Fig. 3, Nos. 1b, 2b). The structure is well developed in a number of genera in the Prioniodinidae and Polygnathidae, especially *Spathodus,* and is extremely large in Pennsylvanian genera of the Polygnathidae.

The escutcheon is of especial value in relating the Polygnathidae to the "typical conodonts." Ulrich and Bassler (1926, 2) expressed some doubt as to whether the Polygnathidae are true conodonts and regarded conodonts as a polyphyletic group. The presence of an escutcheon, an aboral keel and the apparent insertion of the denticles in the carina link the Polygnathidae rather closely to the Prioniodinidae and indicate that *Polygnathellus, Polygnathus,* and *Gondolella* were probably derived from *Spathodus* and that *Spathodus* may have come from *Bryantodus* or *Pri-*

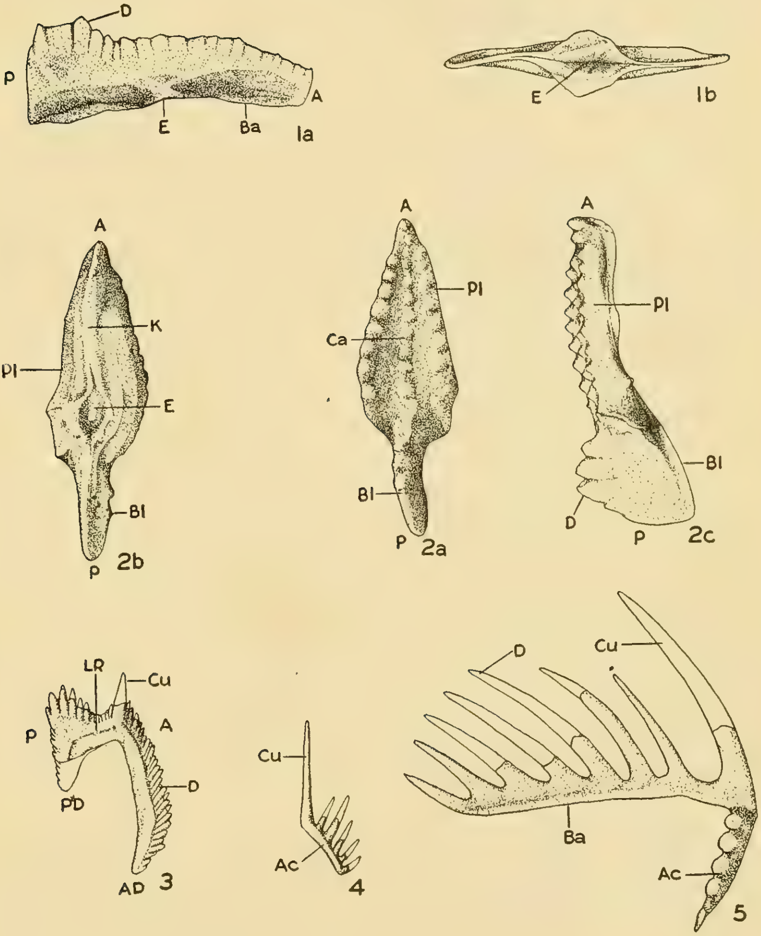
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Figure 3. Plate illustrating the morphology of conodonts. 1a-b. **Spathodus strigilis**, new species (holotype), a. lateral view, b. aboral view. 2a-c. **Polygnathus scapha**, new species (holotype), a. oral view, b. aboral view, c. lateral view. 3. **Falcodus angulus**, new species (paratype). 4. **Ligonodina arcuata**, new species, end view. 5. **Ligonodina hindei** Ulrich and Bassler. **A** anterior, **AC** anticusp, **AD** anterior deflection, **Ba** bar, **Bl** blade, **Ca** carina, **Cu** cusp, **E** escutcheon, **D** denticles, **K** keel, **LR** lateral ridge, **PD** posterior deflection, **Pl** plate, **P** posterior. All specimens from the New Albany shale.. x 20. Drawings by Miss Frances Beede.

oniodella. If my interpretation of Plate 12, figure 7, as a young specimen of *Polygnathus*, possibly *P. lacinata*, is correct, this is further evidence that *Polygnathus* was derived from *Spathodus*. The specimen is similar to *Spathodus parvus* and the lateral ridges found on both sides of the specimen could with further enlargement become the plate. *Palmatolepis* may have been derived from *Polygnathellus* as the plate in *Palmatolepis* extends the full length of the carina and is situated at the base of the carina as in *Polygnathellus*. *Gondolella* and *Polygnathus* were apparently derived from *Spathodus* independent of *Polygnathellus* and *Panderodella*. The higher genera of the Polygnathidae could have been derived from *Gondolella* and *Polygnathus*.

It has also seemed useful to name the anterior downward projection typically found in *Prioniodus* and *Ligonodina*. The name *anticusp* is therefore proposed for the "spur" protruding downward below the cusp (see Fig. 3, Nos. 4, 5). The anticusp may or may not be denticulated, and is found in the following genera: *Prioniodus, Subprioniodus, Pachysomia, Euprioniodina, Synprioniodina, Palmatodella*, and *Telumodina*. The anticusp, at least in the first five genera named above, is not the anterior portion of the bar bent downward but a different structure, and in this the anticusp differs from the *anterior deflection* found in such genera as *Falcodus* and *Angulodus*, which is merely a deflected anterior portion of the bar. In *Telumodina* and *Palmatodella* the anticusp may be the anterior portion of the bar, but the structure has been included under the name anticusp because of the sharp angle it makes with the bar.

In *Falcodus, Angulodus*, and *Metaprioniodus* the posterior end of the bar is bent downward and in this paper is called the *posterior deflection* (see Fig. 3, No. 3). The denticles on the posterior deflection are inclined upward and backward in the plane of the bar and cusp.

The laminar internal structure of some conodonts was first noted by Pander, and has since been described by Bryant, Roundy and others. This structure is well shown in some species of *Lonchodina* and *Prioniodina*. *Stereoconus* and *Chirognathus* have a fiberous structure according to Branson and Mehl (1933). The insertion of the denticles in some conodonts was first pointed out by Stauffer and Plummer, 1932, although it was indicated in some of Hinde's figures in 1879. According to Stauffer and Plummer the denticles of some conodonts are not an integral part of the bar but are set in between two elongate sheaths, and when the tooth is treated with hydrochloric acid the denticles frequently fall out. Some species of conodonts have the bar deeply grooved aborally and appear to be made up of two sheaths, but this is not true of all species showing insertion. The ability to see the insertion may be partly a matter of preservation. In specimens showing the structure, the denticles are lighter in color than the bar material, and the lighter color continues into the bar, showing clearly that the denticles are composed of slightly different material from the bar, and the fusing material between the denticles. Whether the lighter color is due to weathering or was originally present is not important, in either case the evidence indicates that the denticles are inserted. Thin sections of *Hindeodella aculeata* show that the denticles continue separate beyond the change of coloration, curve toward the cusp, and disappear into a common channel. The structure is distinctly different from that of the laminar conodonts.

All conodonts have more or less reenforcing material at the base of the cusp and between the denticles, and this material makes the cusp and denticles appear more integrally a part of the bar than is actually the case. The ingrowth of bar material, or fusion of the denticles, occurs when the denticles are closely appressed as they are in such genera as *Bryantodus,* and *Spathodus.*

Usually sufficient material for a complete chemical analysis of conodonts is difficult to obtain, and it is not always possible to determine how much of the original material has been preserved. Pander reported conodonts to be chiefly composed of calcium carbonate, but later analyses have shown more or less calcium phosphate. The most recent analysis was made for Stauffer and Plummer (1932, 21) and showed that the conodonts from the East Mountain shale at Mineral Wells, Texas, contain 30 to 50 per cent calcium phosphate with probably no organic matter. Conodonts from New Albany shale dissolve readily in hydrochloric acid, and give a test for phosphorus.

Orientation.—Ulrich and Bassler regarded the downwardly bent portion of the bar as the anterior end on the assumption that this end represented the attachment to the jaw. Some means of describing the two ends of the bar is necessary and, regardless of whether this is a correct interpretation the terms anterior and posterior are useful. In genera with downward projections at both ends of the bar or without any downward projection, anterior and posterior may be determined by the inclination of the cusp and denticles; the inclination is toward the posterior end. In *Spathodus, Panderodella,* and *Polygnathellus* where the denticles are higher at one end of the bar or crest, the low end is regarded as anterior. In the other Polygnathidae the end of the plate opposite the blade or denticulated portion of the carina is considered as anterior. In some genera, such as *Hibbardella* and *Diplodella,* where the denticles on the two ends of the bar curve toward the cusp, anterior and posterior ends can not be recognized.

Geologic range.—Conodonts probably range throughout the Paleozoic, and became extinct at the end of that time. No Cambrian faunas, however, have yet been described, but the diversity of the early Ordovician fauna indicates that Cambrian faunas will probably be found as suggested by Branson and Mehl (1933, 8). Branson and Mehl also find a marked reduction in the number of genera in the Permian, Phosphoria of Wyoming, and, together with their failure to find conodonts in the Mesozoic, consider this as evidence that the group died out at the end of the Permian. Gunnell (1932, 324), however, says "in the Cretaceous strata there occurs an undescribed genus intermediate in shape between a tooth of the modern Petromyzon (Cyclostomata) and certain Pennsylvanian conodonts." The "undescribed genus" is apparently not a conodont. Harris and Hollingsworth (1933, 195) in proposing the genus *Icthyodus* give its range as Pennsylvanian to Recent?, but there is some doubt as to whether the genus is a conodont, and in any case it probably does not range into the Mesozoic.

Occurrence, associations, and habitat.—Conodonts occur in all kinds of sediments, but are more abundant in shales. Some sandstones yield considerable numbers of specimens; limestones and calcareous shales rarely have any conodonts, and in the black fissile shales the conodonts occur in profusion only in minute layers, and the greater part of these shales is almost barren.

Associated with the conodonts are found fish plates, sharks teeth, small black conical teeth, scolecodonts, brachiopods, especially *Lingula* and *Orbiculoidea,* Ostracods, Pteropods, spores and other fossils. Ordinarily where conodonts are abundant, few other fossils are found.

The habitat of conodonts is hard to determine; that they were probably marine is shown by the associated fossils, but they probably did not live in warm, shallow seas or the associated fossils would be more abundant. Also if they had lived in the warm shallow seas they should be more abundant in limestones. Their occurrence in black shales makes their habitat even more doubtful because of the lack of agreement as to the condition necessary for the formation of black muds. Conodonts may not have lived under the conditions required for black mud deposition, as is indicated by their layer-like occurrence, but were there killed and preserved. Their abundance under conditions not optimun for other organisms makes them extremely useful for stratigraphic purposes.

LOCALITY LIST

1. New Albany shale, 0-3 feet below the Rockford formation, Falling Run Creek, below the Spring Street, electric railway bridge, New Albany, Indiana.

2. New Albany shale, 0-2 feet below the Rockford formation, in the bed of Caney Fork, where the road crosses the creek, near the center of the west line of Grant 253, about 1½ miles southwest of Henryville, Indiana.

3. New Albany shale, 1-7 feet below the Rockford formation, in creek bed north of the road, about ⅛ of a mile east of Mt. Tabor Church, near the center of the N. E. ¼, Grant 62, north of New Albany, Indiana.

4. New Albany shale, about 3-10 feet below the Rockford formation, creek bed, near the center of Grant 227, northwest of Otisco, Indiana.

5. New Albany shale, 2 feet below the Rockford formation, in the creek bed near the N. E. corner of Grant 85, about 5½ miles north of New Albany, Indiana.

6. New Albany shale, 0-3 feet below the Rockford formation, in the bed of Jacob's branch, near the N. W. corner of Grant 86, north of New Albany, Indiana.

8. New Albany shale, 0-5 feet below the Rockford formation, creek bed, where road crosses the creek N. of the center of the west line of Grant 296, southeast of Vienna, Indiana.

9. Near the top of the New Albany shale just above the gray-green shale containing Devonian Brachiopods, west side of U. S. Highway 31, about 2 miles north of Rockford, Indiana.

10. New Albany shale from near the top of the formation thrown out from the excavation for the water works dam at Rockford, Indiana.

11. New Albany shale, 0-5 feet below the Rockford formation, where U. S. 31 crosses a small creek, N. W. corner of Grant 271, about 1 mile north of Henryville, Indiana.

12. Near top of New Albany shale, creek bed near the center of Sec. 2, T. 2 N., R. 7 E., four miles east of Vienna, Indiana.

13. New Albany shale, 3-10 feet below the Rockford formation, road cut on the old route of U. S. Highway 31, on west line of Grant 255, ½ mile south of Henryville, Indiana.

14. New Albany shale, 3-6 feet below the Rockford formation, road cut in the S. E. ¼ Grant 223, on the Henryville-Charlestown road about 3 miles southeast of Henryville, Indiana.

16. Same Locality, 15 feet below the Rockford formation.

17. Same Locality, 25 feet below the Rockford formation.

18. Same Locality, 30 feet below the Rockford formation.

19. New Albany shale, about 50 feet below the Rockford formation, road cut on the Henryville-Charlestown road, near the northeast corner of Grant 223, about 2½ miles southeast of Henryville, Indiana.

20. New Albany shale, about 40 feet below the Rockford for-

mation, 50 feet above water level of Silver Creek, in the bed of a small creek tributary to Silver Creek, where U. S. 31-W crosses in the N. E. ¼ of Grant 44, about 2 miles north of New Albany, Indiana.

21. New Albany shale, about 30 feet below the Rockford formation, road cut at the junction of U.S. 31-W. and Mt. Tabor road, S. W. corner of Grant 63, north of New Albany, Indiana.

22. New Albany shale, 50 feet above water level of Silver Creek, road cut on the Memphis-Charlestown road, N. E. ¼ Grant 186, 1 mile southeast of Memphis, Indiana.

23. New Albany shale, Ohio River bank, Sec. 10, T. 3 S., R. 6 E, south of New Albany, Indiana. Probably about 20 feet below the Rockford formation.

26. New Albany shale, 0-3 feet above the Beechweed limestone, between U. S. Highway 31, and electric railroad tracks, 2 miles north of Speed, Indiana.

27. New Albany shale, 0-2 feet above the Silver Creek limestone, creek bed, Chelsa, Indiana.

28. New Albany shale, 0-2 feet above the Silver Creek limestone, creek bed near the N. E. corner of Sec. 6, T. 2 N., R. 9 E., 1 mile west of Chelsa, Indiana.

29. New Albany shale, 0-2 feet above the Silver Creek limestone, near the center of Grant 154, 2½ miles northwest of Charlestown, Indiana.

30. New Albany shale, 0-1 foot above the Beechwood limestone, railroad cut at Gibbson's Crossing, near Prather, Indiana.

31. New Albany shale, 0-3 feet above Beechwood limestone, near the center of Grant 136, 1½ miles northwest of Charlestown, Indiana, on the Charlestown-Henryville road.

32. New Albany shale, about 10 feet above the Beechwood limestone, railroad cut, at Prather, Indiana.

33. Sandstone in the New Albany shale, 15 feet (barometer) above the Middle Devonian limestone, in the bed of a small creek tributary to Six Mile Creek, about 150 yards downstream from U. S. Highway 50, 5 miles west of North Vernon, Indiana, and 1½ miles east of Hayden, Indiana.

PROBABLE TAXONOMIC POSITION OF CONODONTS

Pander, who first described conodonts, considered them to be the teeth of primitive fishes similar to the Selachians or sharks. Since Pander's original work many other suggestions have been made as to their probable taxonomic position. They have been regarded as annelid jaws, lingual teeth of naked molluscs, and the spines attached to Crustacean carapaces. Stauffer and Plummer (1932) have given an excellent resume of the history of these various classifications and it need not be repeated here. Recently all workers on the group have regarded conodonts as the teeth of primitive fishes, probably closely related to the Cyclostomata and Elasmobranchii.

The evidence of the vertebrate affinities of conodonts is rather conclusive. As Stauffer and Plummer (1932, 20-21) have pointed out, their chemical composition is different from the chitinous or horny teeth of Chaetopoda or Mollusca, and the spines of Crustacea, but is similar to that of vertebrate teeth. Material found attached to conodonts also appears to be vertebrate. Branson and Mehl (1931, 1) consider the substance they found attached to conodonts as bony, and certainly vertebrate although not having the ordinary structure of bone. Bryant (1921, 26) reported finding a specimen of *Polygnathus rotundiloba* attached orally to a fish plate, possibly an Arthodire. Kirk (1929, 495) found conodonts attached basally to plates regarded as belonging to Ostracodermi; and Stauffer and Plummer (1932, 19-20) report that the Middle Ordovician conodonts from Kansas are attached to a substance which can not be recognized as bone, and much less the plate of any fish. A few of the New Albany conodonts have been found attached to a black brittle substance not recognizable as bone. "Dermal plates", such as those figured by Bassler (1932, pl. 26, figs. 28-30) are found in the New Albany shale associated with conodonts but they are not nearly as abundant as the conodonts. If these "dermal plates" belonged to the same animal as the conodonts it is surprising that they are not more abundant, inasmuch as *Lingula* and *Orbiculoidea* are preserved at the same horizon. The association of conodonts and fish plates, while not conclusive is evidence of the vertebrate nature of conodonts.

Some conodonts, especially the Polygnathidae, show signs of wear (see Plate 8, Fig. 41), but this is not common and the great majority show no signs of wear. If conodonts are teeth it would appear that some sign of wear should be more common than it is. It is possible that conodonts were arranged in rows as are the teeth of sharks, cast off, and replaced from time to time; or that the feeding habits required only holding of the prey until swallowed. On the other hand, the fact that the denticles are frequenly inserted, and that the delicate forms apparently evolved into the massive crushing plates (Polygnathidae) make it appear that conodonts must be teeth. If conodonts are to be considered teeth some better explanation of the lack of wear is needed. In such genera as *Ligonodina* with the denticles on the bar and anticusp in different planes it is difficult to see how they can be placed in a jaw in any useful manner.

Gunnell (1932, 324) has reported finding an undescribed genus in the Cretaceous that he regards as intermediate between conodonts and modern Cyclostomata (Petromyzon). When this genus is described it may offer good evidence for the classification of conodonts.

It is obvious that neither the classification nor the function of conodonts has been proved. The genera and species which have been described are probably not all from different animals, and several diverse types may have belonged to the same individual. Until material is found that shows this to be the case the interests of stratigraphic geology will be best served by describing as many genera and species as are useful in the determination of horizons.

For the present conodonts are best included under the Cyclostomata, because this Class includes the most primitive vertebrates with similar tooth structures. The Orders of the Cyclostomata are based on soft parts, and until more is known about the soft parts of conodonts they are best placed as an extinct order of the Cyclostomata.

SYSTEMATIC DESCRIPTIONS

Class CYCLOSTOMATA

Order CONODONTA

Small tooth-like or jaw-like structures, amber colored and translucent, with a resinous luster; composed of calcium phosphate and calcium carbonate; and consisting of a single, simple cusp, or base and accessory denticles, or denticulate bar, with or without cusp, or plates with blade or carina. Frequently they are shaped into rights and lefts as if belonging to opposite sides of the mouth or jaw.

Family DISTACODIDÆ Ulrich and Bassler, 1926

Conodonts consisting of a single simple cusp with smooth basal expansion.

The family includes the following genera: *Distacodus* Hinde, 1879 (*Machairodus* Pander, 1856, preoccupied, *Machairodia* Smith, 1907), *Acodus, Acontiodus, Drepanodus, Scolopodus, Oistodus,* and *Paltodus* Pander, 1856; *Scolopodella* Stauffer and Plummer, 1932, *Stereconus* Branson and Mehl, 1933. *Lepodus* Branson and Mehl 1933, and *Icthyodus* Harris and Hollingsworth, 1933, belong the the family if they are conodonts.

Family BELODIDÆ, new family

Conodonts consisting of a single cusp and accessory denticles or small base with a few discrete denticles.

The family includes the following genera: *Belodus* and *Cordylodus* Pander, 1856, *Idioprioniodus* Gunnell, 1933, *Cornuramia* Smith, 1907, *Erismodus, Cardiodus, Polycaulodus, Microcoelodus, Pteroconus, Phragmodus,* and *Chirognathus* Branson and Mehl, 1933.

Family PRIONIODIDÆ Ulrich and Bassler, 1926

Conodonts with denticulate bar and cusp; with anticusp, or cusp situated near the anterior end of the bar.

The family includes the following genera: **Prioniodus* Pander, 1856; *Subprioniodus* and *Pachysomia* Smith, 1907; **Euprioniodina,* **Ligonodina,* **Synprioniodina,* **Palmatodella,* and **Hindeodella,* Ulrich and Bassler, 1926; **Hamulosodina* and *Telumodina* Cooper, 1931; **Hindeodelloides,* new genus, and **Metaprioniodus,* new genus.

Family PRIONIODINIDÆ Ulrich and Bassler, 1926

Conodonts with denticulate bar, with or without cusp; cusp, if present, situated in the median third of the bar.

The family includes the following genera: **Prioniodina*, **Prioniodella*, **Lonchodina*, **Hibbardella*, *Diplododella*, and **Byrantodus* Ulrich and Bassler, 1926; *Dichognathus*, *Plectospathodus*, *Ozarkodina*, **Spathodus*, *Coleodus*, *Oulodus*, *Neocoleodus*, and *Trichognathus*, Branson and Mehl, 1933; **Falcodus*, new genus, and **Angulodus*, new genus. *Dichognathus*, *Plectospathodus*, and *Ozarkodina* are similar to *Bryantodus; Coleodus* is similar to *Spathodus.*

Family POLYGNATHIDÆ Ulrich and Bassler, 1926

Conodonts with plate and denticulate carina or blade; plate developed on one or both sides of the carina.

The family includes the following genera: **Polygnathus* Hinde 1879; *Ancyrodella*, *Panderodella*, **Polygnathellus*, and **Palmatolepis*, Ulrich and Bassler, 1926; **Gondolella* and *Streptognathodus* Stauffer and Plummer, 1932; *Idiognathodus* Gunnell, 1931; *Cavusgnathus*, and *Idiognathoides*, Harris and Hollingsworth, 1933; *Polygnathodella* Harlton, 1933; *Trucherognathus*, *Polygnathoides*, *Amorphognathus* and *Amabalodus* Branson and Mehl, 1933.

The following genera are not recognizable: *Gnathodus*, *Centognathus*, and *Lonchodus*, Pander, 1856; *Valentia*, Smith, 1907.

The following genera are not conodonts: *Prioniognathus* Pander, 1856, *Holmesella* and *Fortscottella* Gunnell, 1931; *Bransonella* and *Multidentodus* Harlton, 1933.

Probably not all of the genera included in the above family descriptions are valid and recognizable, but the writer has not had sufficient material to determine the validity of all the genera, especially those which occur in the Ordovician and Silurian.

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*Genera described in this paper from the New Albany shale.

KEY TO FAMILIES AND GENERA IN NEW ALBANY SHALE

- Conodonts with denticulate bar, and cusp situated near the anterior end of the bar ... PRIONIODIDAE
  - With anticusp
    - Anticusp not denticulate ... *Prioniodus*
    - Anticusp denticulate
      - Entire anticusp denticulate
        - Denticles on the anticusp in the plane of the bar and cusp
          - Anticusp short, and cusp sharply inclined to the bar
            - Denticles separate ... *Euprioniodina*
            - Denticles closely appressed ... *Synprioniodina*
          - Anticusp long, and cusp in the horizontal plane of the bar or slightly tilted upward ... *Palmatodella*
        - Denticles on the anticusp not in the plane of the bar and cusp
          - All denticles rounded and separate ... *Ligonodina*
          - All denticles laterally compressed and closely appressed ... *Hindeodelloides*
      - Anticusp not entirely denticulate ... *Hamulosodina*
  - Without anticusp
    - Without posterior downward projection ... *Hindeodella*
    - With posterior downward projection ... *Metaprioniodus*

- Conodonts with denticulate bar, with or without cusp, cusp if present situated in the median third of the bar ... PRIONIODINIDAE
  - With cusp
    - Tooth asymmetrical
      - Denticles separated
        - Bar arched upward, but not laterally bowed ... *Prioniodina*
        - Bar arched upward and laterally bowed ... *Lonchodina*
      - Denticles closely appressed
        - Without posterior downward deflection ... *Bryantodus*
        - With posterior downward deflection
          - Anterior end slightly deflected downward ... *Angulodus*
          - Anterior end sharply deflected downward ... *Falcodus*
    - Tooth symmetrical ... *Hibbardella*
  - Without cusp, or cusp not readily recognizable
    - Bar nearly straight
      - Denticles short, and almost entirely fused ... *Spathodus*
      - Denticles long, needle-like and separate ... *Prioniodella*
    - Bar arched upward and laterally bowed ... *Lonchodina*
- Conodonts with plate, or carina with lateral flange or flanges POLYGNATHIDAE
  - With blade ... *Polygnathus*
  - Without blade
    - Carina predominate and a flange on both sides *Polygnathellus*
    - Plate predominate
      - Plate leaf shaped ... *Palmatolepis*
      - Plate canoe shaped ... *Gondolella*

Family PRIONIODIDÆ Ulrich and Bassler, 1926

Conodonts with denticulated bar and cusp; with anticusp or with the cusp situated near the anterior end of the bar.

Genus PRIONIODUS Pander, 1856

Typically pick-shaped conodonts with short bar, large terminal cusp and anticusp; anterior line formed by cusp and anticusp nearly straight; denticles numerous, discrete or rarely fused, and appear to be inserted. Rarely denticles can be seen in the anterior face of the anticusp.

Genotype.—*Prioniodus eleganus* Pander, 1856. (First species, selected by Ulrich and Bassler, 1926). Lower Ordovician, Baltic Provinces.

Prioniodus alatus Hinde — Plate 1, figs. 1, 2, 3

Prioniodus? alatus Hinde, 1879, Quart. Jour. Geol. Soc. London, vol. 35, p. 361, pl. 16, fig. 5. Genesee (Upper Devonian), North Evans, New York.

Prioniodus alatus Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, p. 15, pl. 3, fig. 10, pl. 4, fig. 1-7. Same locality as Hinde's.—Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 11, pl. 1, figs. 25, 26. Rhinestreet Shale (Portage, Upper Devonian), Shaleton, New York.—Branson and Mehl, 1933, University of Missouri Studies, vol. 8, p. 134, pl. 11, fig. 13. New figure of holotype.

Bar short, heavy, and straight; cusp large, laterally compressed, sharp edged and forming a straight anterior line with the large anticusp; denticles decreasing in size from the cusp toward the posterior end of the bar, closely appressed, free at tips only, and apparently inserted. Sometimes an indication of denticles may be seen in the anterior edge of the anticusp, and for this reason the species may not belong to *Prioniodus*. Length, about 2.5 mm.

Plesiotypes.—Indiana University Paleontological Collection, No. 1921, lower New Albany shale, Locality 32, Prather, Indiana; No. 1922, upper New Albany shale, Locality 6, north of New Albany, Indiana; No. 1923, upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Common in upper New Albany shale at Locality 1, rare at localities 2, 3, 6, 8, 10, and 14; rare in lower New Albany shale at Localities 26, 32, and 33.

Prioniodus alatoideus Cooper — Plate 1, figs. 4, 5

Prioniodus alatoideus Cooper, 1931, Jour. Paleon. vol. 5, p. 232, pl. 28, fig. 1. Woodford fmn., sec. 3, T. 2 N., R. 6 E., Oklahoma.

Tooth small with short, thin, laterally compressed bar; cusp, long, narrow, gradually tapering, sharp edged, rounded on one side and flattened on the other side; denticles numerous, 20 to 24, long, slender, apparently deeply inserted, and closely appressed. Anticusp subtriangular with anterior edge forming a straight line with the cusp and the posterior edge perpendicular to the bar. Length, 0.8-1.6 mm.

The species differs from *P. alatus* and *P. alatoides* in having a narrower cusp and numerous slender denticles. Cooper's specimen from the Woodford is considerably smaller than the specimens from the New Albany shale, but the inclination of cusp and general proportions are similar.

Plesiotypes.—Indiana University Paleontological Collection, No. 1924, upper New Albany shale, Locality 1, New Albany, Indiana; No. 1925, upper New Albany shale, Locality 14, southeast of Henryville, Indiana.

Occurrence.—Upper and middle New Albany shale; abundant at Locality 3; common at Localities 1, 2, 6, and 14; rare at Localities 8, 10, and 20.

Prioniodus macrocornatus Cooper Plate 1, fig. 6

Prioniodus macrocornatus Cooper. 1931. Jour. Paleon, vol. 5, p. 234, pl. 28, fig. 2. Woodford formation, Oklahoma.

Bar straight and relatively thin in comparison to the cusp; denticles acutely pointed, inserted and well separated; cusp large, ovate in cross section, sharply inclined and probably acutely pointed; anticusp small with posterior side perpendicular to the bar.

The species is characterized by the extremely large cusp which makes the bar and denticles appear small. It differs from *P. alatoides* in having the cusp more sharply inclined as well as larger proportionately.

Specimens of the species from the New Albany shale seem to differ from the holotype in having a shorter cusp and longer, more numerous denticles. The inclination of the cusp and relative proportions of the cusp and bar are, however, very similar. Length, about 2 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1920, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Genus HINDEODELLA Ulrich and Bassler, 1926

Bar long and thin with the cusp situated near the anterior end. Denticles usually fine, needle-like and alternating in size. No escutcheon.

Genoholotype.—*Hindeodella subtilis* Ulrich and Bassler, 1926. Hardin sandstone, Mt. Pleasant, Tenn.

Hindeodella priodon, new species Plate 4, fig. 16

Bar rounded, thick, relatively slender, with the anterior portion slightly down curved and laterally bowed, posterior portion nearly straight. Cusp straight, inclined, rounded, and gradually tapering; posterior denticles relatively coarse, similar to the cusp in shape, and alternating with usually 3 smaller denticles between the large ones, usually 5 anterior denticles separated, increasing in size toward the end of the bar, longer and more slender than the posterior ones. None of the denticles appear to be inserted. Length, 1.4—2 mm.

The essential characters of the species are the straight cusp, rounded bar, coarse denticles, and the separation and lack of alternation of the anterior denticles. It differs from *H. alternata* Ulrich and Bassler in having a bar more slender in proportion to length, and having the posterior alternating denticles aligned; from *H. rotunda* Hibbard in lacking the alternation of the anterior denticles.

Holotype.—Indiana University Paleontological Collection, No. 1855, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Lower New Albany shale, abundant at Locality 31; common at Locality 27; rare at Localities 26, 28, 29, 30 and 31.

Hindeodella species Plate 4, fig. 17

Bar heavy, broad, and laterally compressed, with the anterior portion sharply deflected downward to form a hook. Cusp erect and rounded; denticles short, laterally compressed, and rounded; posterior denticles alternating in size with two to four small ones between the larger, about five subequal anterior denticles; no insertion apparent. Length of figured specimen, 1.6 mm.

Differs from *H. priodon* in having the anterior end of the bar hooked, and the whole bar laterally compressed. The species is probably new but is known from only one specimen and is therefore not named.

Indiana University Paleontological Collection, No. 1856, lower New Albany shale, Locality 26, north of Speed, Indiana.

Hindeodella catacta, new species Plate 4, fig. 18

Tooth small, with bar short, laterally compressed and thin; anterior portion long and slightly deflected downward. Cusp inclined, laterally compressed, straight, slender, and acutely pointed; denticles fine, flattened, thin, and both anterior and posterior denticles alternating with usually two small denticles between the large ones; none of the denticles appear to be inserted. Length of holotype, 1.1 mm.

This species is characterized by the small, thin bar with long anterior portion.

Holotype.—Indiana University Paleontological Collection, No. 2275, upper New Albany shale, Locality 3, north New Albany, Indiana.

Occurrence.—Rare in upper New Albany shale at Localities 1, 3, 4, 6, 8, 10, and 14.

Hindeodella aculaeta, new species Plate 4, figs. 19, 20, 21; pl. 5, figs. 2, 3

Posterior portion of the bar straight or slightly curved, thick and rounded, with distinct oral shoulder near the cusp, becoming thin and flattened without oral shoulder toward the end of the bar; anterior portion sharply bowed inward and expanded downward. Cusp rounded, acutely pointed, and gently curved; denticles rounded and needle-like, with regular alternation of both the anterior and posterior denticles, 3 to 4 small denticles between the larger ones and 14 to 20 large denticles in the posterior set, and 5 to 7 large denticles in the anterior set with one small denticle between the larger ones; cusp and denticles apparently inserter. Length, 2.4—3.6 mm.

Holotype..—Indiana University Paleontological Collection, No. 2274, upper New Albany shale, Locality 3, northeast of New Albany, Indiana; Paratype No. 1850, upper New Albany shale, Locality 6, northeast of New Albany, Indiana; Paratypes Nos. 2288, 2289, middle New Albany shale, Locality 20, north of New Albany, Indiana; Paratype No. 2267, middle New Albany shale, Locality 21, north of New Albany, Indiana.

Occurrence.—Middle and upper New Albany shale, abundant at Localities 1, 6, 20, and 21; common at Localities 2, 3, 8, and 9; rare at Localities 10, 11, 18, and 19.

Hindeodella grandis, new species Plate 4, fig. 22

Bar heavy, broad, laterally compressed and rounded, anterior end deflected downward and slightly bowed laterally. Cusp slender, rounded, acutely pointed, and gently curved near the tip; denticles laterally compressed, acutely pointed, and regularly alternating, 2 or 3 small denticles between the larger ones posterior to the cusp, and one small denticle between the larger ones anterior to the cusp; denticles apparently inserted. Length of holotype, 4.1 mm.

The species is characterized by its large size, and the extreme difference in size of the alternating denticles.

Holotype.—Indiana University Paleontological Collection, No. 2270, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 3, 9, 11, and 13.

Hindeodella species Plate 5, fig. 1

Bar broad, laterally compressed, nearly straight in the posterior portion and abruptly deflected downward, but not laterally bowed anterior to the cusp. Cusp short, straight, laterally compressed, and gradually tapering; denticles similar to the cusp in shape, unequal in length but without regular alteration; denticles apparently inserted. Length of figured specimen, 2 mm.

Indiana University Paleontological Collection, No. 1853, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Two specimens from upper New Albany shale, one from Locality 1 and the other from Locality 6.

Hindeodella compressa, new species Plate 5, fig. 4

Bar broad, flattened, and nearly straight except for the slightly deflected anterior end; cusp small, narrow, and not easily distinguished; cusp and denticles closely appressed, and apparently inserted; posterior denticles alternating in size with usually two small denticles between the larger ones, larger set abruptly pointed, small set more needle-like; about 8 short denticles on the anterior deflection. Length of holotype, 2.1 mm.

The species differs from *H. laticlavis* in having a shorter bar and cusp.

Holotype.—Indiana University Paleontological Collection, No. 1858, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1 and 6.

Hindeodella elongata, new species Plate 5, figs. 5, 6

Bar very long, and slender; straight in the posterior portion, and gently deflected downward in the anterior portion. This deflection is in the plane of the bar and not bowed inward as is common in species of *Hindeodella*. Cusp situated at the point of deflection, needle-like, small and sometimes difficult to distinguish. Posterior denticles numerous, fine, needle-like and alternating, usually with four small denticles between the larger ones. Near the posterior end of the bar there are sometimes only two small denticles between the larger ones. Anterior denticles similar in shape to the posterior ones, but usually somewhat longer. The anterior denticles alternate with two small denticles between the larger ones. Length of holotype, 1.7 mm.

H. elongata is easily distinguished by its extremely long, slender bar and numerous fine denticles. It differs from *H. multidens* Holmes by having alternation of denticles, and more slender bar.

Holotype.—Indiana University Paleontological Collection, No. 1848, Paratype No. 1849, both types from upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Common in the upper New Albany shale at Localities 1, 3, 6, 8, 9, 10, and 14; rare at Localities 5, 11, 12.

Hindeodella species Plate 5, fig. 7

Bar heavy, laterally compressed, straight in the posterior portion, and anterior portion abruptly deflected downward and turned so that the denticles are perpendicular to the bar and cusp. Cusp unknown; denticles laterally compressed, rounded, and abruptly pointed, posterior denticles alternating in size with 1 or 2 small denticles between the large ones, 6 large denticles anterior to the cusp without regular alternation; cusp and denticles apparently inserted. Length of figured specimen, 2.2 mm.

Indiana University Paleontological Collection, No. 1845, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—One specimen from above locality.

Hindeodella laticlavis, new species Plate 5, figs. 9, 10

Posterior portion of the bar broad, thin, with sublenticular cross section, and nearly straight base; anterior portion deflected and expanded downward, and slightly bowed laterally Cusp nearly straight, laterally compressed, and acutely pointed; denticles laterally compressed, and sharply pointed, with regular alternation, two or three small denticles between the larger ones posterior to the cusp, and one small denticle between the larger ones anterior to the cusp; 10 to 14 large denticles posterior to cusp; both cusp and denticles apparently inserted. Length of holotype, 2.5 mm.

The species is distinguished from *H. aculeata* in having a bar with lenticular cross section, anterior portion of the bar deflected, fewer denticles, and lacking an oral shoulder near the cusp.

Holotype.—Indiana University Paleontological Collection, No. 1854, Paratype No. 2356, both types from New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Upper New Albany shale, common at Localities 1, 2, 3, and 6; rare at Localities 8, 9, 10, 11, and 12.

Hindeodella gracilis, new species Plate 5, fig. 11

Bar thin, narrow and straight except for the anterior deflection which curves downward and inward. Cusp rounded, long, slender, acutely pointed and gently curved. Denticles inserted, slender, needle-like, and there is alternation of both the anterior and posterior denticles, with two or three small denticles between the larger ones; four or five of the larger denticles are anterior to the cusp. Length, about 2.5 mm.

The species is characterized by the thin bar, fine posterior denticles and the long, slender, alternating denticles anterior to cusp.

Holotype.—Indiana University Paleontological Collection, No. 1857, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Lower New Albany shale, abundant at Locality 31; common at Locality 27; rare at Localities 26, 28, 29, and 30.

Hindeodella alternidens, new species Plate 5, figs. 12, 13

Bar long, thin, laterally compressed, and slightly curved, posterior portion narrow near the cusp and becoming broader; cusp needle-like, and slightly curved; denticles numerous, regularly alternating with one to three small denticles between the larger ones; all denticles flattened, thin, acutely pointed, and not inserted. Anterior portion of the bar bent slightly downward and strongly curved laterally; and bears more than eight irregularly alternating denticles. Length, about 2.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 1842, Paratype No. 1843, both types from upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Upper New Albany shale; abundant at Locality 1; common at Localities 2, 10, and 14; rare at Localities 3, 6, 8, 9, and 13.

Hindeodella angulus, new species Plate 5, fig. 14

Bar heavy, and rounded, straight in the posterior portion and sharply deflected downward anterior to the cusp. Cusp rounded, slender, erect, and straight or gently curved; denticles laterally compressed, rounded, broad at base and acutely pointed, six or more anterior denticles curve gently toward the cusp without regular alternation, but there may be one or two small denticles between some of the larger denticles; posterior denticles alternating with one or two small denticles between the larger ones. Length, about 2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2315, lower New Albany shale, Locality 32, Prather, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 30, and 32.

Hindeodella deflecta Hibbard Plate 5, fig. 15

Hindeodella deflecta Hibbard, 1927, Amer. Jour. Sci., 5th ser., vol. 13, pp. 207-208, fig. 4c. Middlesex shale (Upper Devonian, Portage), 18 mile Creek, Erie County, New York.

Bar short, laterally compressed, straight in the posterior portion, and deflected downward in the anterior portion; cusp inclined, nearly straight, broad at base and gradually tapering; posterior denticles similar to cusp in inclination, alternating in size, with one or two small denticles between the larger ones, and flattened; some specimens show apparent insertion; all denticles increase in size toward the ends of the bar; last posterior denticle extends as a continuation of the bar; about 4 anterior denticles present. Length, about 1.2 mm.

Species somewhat similar to *H. alternata* Ulrich and Bassler, but differs in having a shorter bar and greater inclination of the cusp and denticles.

Plesiotype.—Indiana University Paleontogical Collection, No. 1846, upper New Albany shale, Locality 2, south of Henryville, Indiana.

Occurrence.—Rare in middle and upper New Albany shale at Localities 2, 4, 6, 10, and 20.

Hindeodella emacerata, new species Plate 5, fig. 16

Bar short, thin and sharply deflected downward in the anterior portion. Cusp rounded, acutely pointed, inclined and nearly straight. Denticles similar to the cusp in shape and inclination, alternating, with two or three small denticles between the larger set on the posterior portion of the bar; four to six subequal anterior denticles without alternation. All denticles apparently not inserted; inclined, and relatively coarse. Length of holotype, 1.5 mm.

The species is distinguished by the sharp anterior deflection, anterior denticles without alternation, relatively coarse denticles, and lack of apparent insertion.

Holotype.—Indiana University Paleontological Collection, No. 1852, upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Common in the upper part of the New Albany shale, Localities 1, 2, 3, 6, 8, 9, and 14. Rare at Localities 4, 5, 10, 11, 12, and 13.

Hindeodella panderi Hibbard Plate 5, fig. 17

Hindeodella panderi, Hibbard, 1927, Amer. Jour. Sci., 5th ser., vol. 13, p. 205, fig. 4g. Middlesex and Rhinestreet shales (Upper Devonian, Portage), Erie County, New York.

Bar slightly curved, laterally compressed and rather thin, anterior portion bowed and expanded downward. Cusp slender, straight or slightly curved, and rounded; denticles fine and needle-like, with alternation, 2 or 3 small denticles between the larger ones posterior to the cusp; and usually one small denticle between the larger ones anterior to the cusp; both denticles and cusp appear to be inserted. Length, about 1.5 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 2266, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Upper New Albany shale, common at Locality 1; rare at Localities 3, 6, 8, 10, and 14.

Hindeodella tenerrima Holmes? Plate 5, fig. 18

Hindeodella tenerrima Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 25, pl. 9, figs. 6, 7. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Bar rounded, slender, and curved downward at the posterior end; cusp rounded, slender and gently curved; denticles separated, rounded, and acutely pointed. Length, about 3.5 mm.

The specimen from the New Albany shale questionably referred to the species shows an indication of alternation with two small denticles between the larger ones on the posterior part of the bar.

Indiana University Paleontological Collection, No. 2287, upper New Albany shale, Locality 9, north of Rockford, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 9, and 10.

Hindeodella species Plate 5, fig. 19

Bar heavy, laterally compressed, rounded and gently arched upward. Cusp long, slender, and rounded; denticles slender, rounded, acutely pointed, increasing in size toward the middle of the posterior portion of the bar, and alternating with 1 or 2 small denticles between the larger ones; all denticles apparently inesrted. Anterior end of bar unknown.

Only specimen, Indiana University Paleontological Collection, No. 2264, middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Hindeodella jubata, new species Plate 10, fig. 13

Bar short, heavy, and laterally compressed, with the anterior portion sharply deflected downward. Cusp short, rounded, and straight; denticles closely spaced, short, rounded, sharply pointed, apparently inserted, and tending to alternate in size. Length of holotype, 1.5 mm.

The species is characterized by the relatively short bar and sharply deflected anterior portion.

Holotype.—Indiana University Paleontological Collection, No.

2319, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Hindeodella conidens, new species Plate 10, fig. 16.

Bar heavy and rounded, with the anterior portion expanded at the end, slightly deflected downward and sharply bowed inward. Cusp long, slender, rounded, acutely pointed and gently curved. Denticles similar to the cusp in shape; posterior denticles alternating, with one or two small denticles between the larger ones; about 5 denticles anterior to the cusp; none of the denticles appear to be inserted. Length of holotype, 2.6 mm.

Holotype.—Indiana University Paleontological Collection, No. 2260, upper New Albany shale, Locality 9, north of Rockford, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 3, 5, 6, 8, 9, 10, and 14.

Genus HAMULOSODINA Cooper, 1931

Hamulosodina Cooper, 1931, Jour. of Paleon., vol. 5, p. 239.

Tooth consists of slender bar carrying alternating denticles, strong cusp and anticusp. The anticusp denticulated only near the cusp.

Genoholotype.—Hamulosodina bidens Cooper, 1931. Woodford formation, Oklahoma.

Hamulosodina? perangulata, new species Plate 5, fig. 8

Bar slender, flattened, thin and nearly straight, anticusp perpendicular to bar. Cusp erect, slightly curved, slender, and rounded; denticles flattenend, thin, broad at the base and rapidly tapering, those on the bar alternating in size with 2 or 3 small denticles between the larger ones, two or three denticles on the anticusp. Full length of the bar not known.

When the anticusp is broken off of the species it is difficult or impossible to distinguish from *Hindeodella alternidens.*

Holotype.—Indiana University Paleontological Collection, No. 1790, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.—Upper New Albany shale, rare at Localities 1, 2, 3, 8, 13, and 14.

Hamulosodina? species Plate 12, fig. 5

Bar flattened, thin, and curved downward near the cusp; cusp long, slender, gently curved and rounded; denticles short, laterally compressed, irregularly alternating and apparently not inserted. Anticusp unknown, and for this reason the genus can not be determined.

Indiana University Paleontological Collection, No. 2336, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 5, and 6.

Genus HINDEODELLOIDES new genus

Bar laterally compressed, thin, straight or gently curved, with an anticusp which gives the tooth a *T*-shaped appearance similar to the pick shape of *Ligonodina.* The plane including the denticles on the anticusp is inclined to the plane of the bar and cusp. Denticles laterally compressed, closly appressed, and usually alternating in size.

The genus differs from *Hindeodella* in having an anticusp; from *Ligonodina* in the close appression of the denticles; from *Hamulsodina* in that the anticusp is entirely denticulate; and from *Falcodus* in that the denticles on the anticusp are at an angle to the plane of the bar and cusp.

Genoholotype.—Hindeodelloides bicristatus, new species.

Hindeodelloides bicristatus, new species Plate 7, figs. 2, 3; pl. 12, fig. 6

Bar flattened, short, broad at the posterior end and narrow near the cusp; anticusp flattened, and inclined to the plane of the bar and cusp. Cusp flattened, sharp edged, acutely pointed and slightly curved; denticles on the bar thin, acutely pointed, inclined toward the posterior end, and alternating with usually three small denticles between the larger ones; about 6 closely appressed, subequal denticles on the anticusp with one or more small denticles between some of the larger ones; all denticles apparently inserted. Length, 0.6—1.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 1862, upper New Albany shale, Locality 1, New Albany, Indiana; Paratype No. 1863, upper New Albany shale, Locality 3, north of New Albany, Indiana; Paratype No. 1864, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare throughout the New Albany shale at Localities 1, 3, 6, 10, 14, 20, 21, and 27.

Hindeodelloides alatus, new species Plate 7, fig. 7

Bar heavy, laterally compressed, broad at the posterior end and becoming narrow near the cusp. Cusp laterally compressed, sharp edged, slender and gently curved. Posterior denticles laterally compressed, sharp edged, and increasing in size toward the posterior end of the bar, without alternation. Anticusp flattened at right angles to the plane of the bar and carrying eight to ten subequal denticles. All denticles apparently inserted. Length of holotype, 1.5 mm.

Holotype.—Indiana University Paleontological Collection, No. 1865, middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Middle part of the New Albany shale. Common at Locality 20; rare at Localities 18, 19, and 21.

Hindeodelloides minutus, new species Plate 7, fig. 12

Bar short, flattened, thin and slightly arched; anticusp thin, flattened and inclined to the plane of the bar and cusp. Cusp slender, flattened, sharp edged, acutely pointed, and gently curved. Denticles on the bar and anticusp thin, sharp edged, acutely pointed, closely appressed, and apparently inserted. Length, up to 0.5 mm.

The species differs from *H. alatus* in the smaller size and greater inclination of the posterior denticles.

Holotype.—Indiana University Paleontological Collection, No. 2281, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Hindeodelloides, species Plate 10, fig. 9

Bar broad, laterally compressed, thicker near the cusp; denticles on anticusp slightly inclined to plane of bar and cusp; posterior portion slightly bowed downward. Cusp inclined, straight, laterally compressed, sharp edged and acutely pointed. Denticles laterally compressed, broad at the base and rapidly tapering on the posterior portion of the bar; denticles on anticusp more slender. Cusp and denticles apparently inserted.

Known from a single specimen. Length, 0.9 mm.

Indiana University Paleontological Collection, No. 2320, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Hindeodelloides? species Plate 10, fig. 14

Bar short, broad, and thin with the posterior end curved slightly downward; anticusp flattened and very slightly inclined to the plane of the bar and cusp. Cusp long, slender, rounded and slightly curved. Denticles laterally compressed, sharp edged, closely appressed and slender on the bar; discrete and broader on the anticusp.

Known from a single specimen.

Indiana University Paleontological Collection, No. 2298, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Hindeodelloides species Plate 12, fig. 9

Bar thin, flat, and broad; anticusp also thin and flat with the denticles perpendicular to the plane of the bar and the cusp. Cusp slender, straight, rounded, and acutely pointed; denticles on the bar laterally compressed, and alternating in size with 2 small denticles between the larger ones; denticles on the anticusp apparently not alternating.

Known from two broken specimens.

Indiana University Paleontological Collection, No. 2332, upper New Albany shale, Locality 1, New Albany, Indiana.

Hindeodelloides gracilis, new species Plate 12, fig. 12

Bar broad, thin and flattened, with straight base; anticusp long, thin, and inclined to the vertical plane of the bar and cusp. Cusp straight, slender, rounded toward tip, but angulated near base; about three times the length of the largest denticles; denticles numerous, closely appressed, slender, rounded, and alternating with 2 or 4 small denticles between the larger ones; apparently not inserted. Length of holotype, 0.7 mm.

Holotype.—Indiana University Paleontological Collection, No. 2331, upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Rare in the middle and upper New Albany shale at Localities 1, 5, 6, 9, 10, and 20.

Genus EUPRIONIODINA Ulrich and Bassler, 1926

Tooth consisting of cusp, denticulated bar and anticusp with the denticles on the anticusp in the plane of the bar and cusp. The denticles on the bar are separated, and this separation of the denticles distinguishes the genus from *Symprioniodina* which it otherwise resembles.

Genoholotype.—*Euprioniodina deflecta* Ulrich and Bassler, 1926. Rhinestreet shale, (Upper Devonian, Portage), Shaleton, New York.

Euprioniodina species Plate 6, fig. 15

Bar heavy, and rounded with large anticusp; cusp large, laterally compressed, rounded, and inclined at a low angle; denticles separated, rounded, not laterally compressed, long and rather slender. Length of bar and anticusp unknown.

The species is larger, has more separated denticles than *E. perangulata* Ulrich and Bassler, and also appears to lack alternation of denticles on the bar.

Indiana University Paleontological Collection, No. 2295, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Fragments common at Localities 26, and 32, in the lower New Albany shale.

Euprioniodina fornicata, new species Plate 6, fig. 16

Bar heavy, rounded and slightly bowed near the cusp; anticusp short, flattened, deflected less than 90 degrees, and looks like an appendage to the cusp. Cusp long, parallel sided, bluntly pointed, rounded, and somewhat flattened near the base; denticles slender, needle-like, separated on the bar and closely spaced on the anticusp; cusp and denticles apparently inserted. Length of holotype, 2.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 1828, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle and upper New Albany shale at Localities 10, 14, 18, 19, and 20.

Euprioniodina prona, new species Plate 6, fig. 9; pl. 11 fig. 8

Bar long, rounded and slightly bowed near the cusp, becoming flattened and thinner near the end; anticusp large, short, smoothly rounded on convex side with a prominent escutchon on the concave side; cusp short, laterally compressed, broad at the base and bluntly pointed, inclined forward at an angle of about 27 degrees; denticles on the bar 20 to 24, needle-like, short and closely spaced, but not fused, with some alternation in size near the cusp; 10 to 12 closely spaced, and somewhat fused denticles on the anticusp; all denticles apparently inserted. Length, up to 3 mm.

Holotype.—Indiana University Paleontological Collection, No. 1788; Paratype No. 1789, both types from upper New Albany shale, Locality 9, north of Rockford, Indiana.

Occurrence.—Abundant in the upper New Albany shale at Localities 1, 3, 6, and 10; common at Localities 8, and 14; rare at Localities 5, 9, 11, and 13.

Euprioniodina devexa, new species Plate 11, fig. 4

Bar heavy, and rounded; anticusp short, thinner than bar and looks like an appendage to the cusp. Cusp rounded, shapely pointed and inclined to the bar at an angle of about 20 degrees. Denticles slender, rounded, closely spaced, and apparently deeply inserted. Small escutcheon present. Length, about 2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2290, Locality 23, south of New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Locality 23.

Euprioniodina perangulata Ulrich and Bassler Plate 11, fig. 5

Euprioniodina perangulata Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 30, pl. 3, fig. 10. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Tooth small; bar rounded and slightly curved; anticusp long, slender, nearly straight and rounded; cusp laterally compressed, broad at the base, gradually tapering, and inclined to the bar at an angle of about 50 degrees; denticles rounded and slender, closely spaced on the anticusp, and separated on the bar with obscure, irregular alteration in size.

Both the holotype and the specimens from the New Albany shale appear to be broken and therefore the full length and number of denticles on the bar and anticusp are unknown.

Plesiotype.—Indiana University Paleontological Collection, No. 2323, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Commonly represented by fragments in the lower New Albany shale at Localities 26, 30, and 32.

Euprioniodina debilis, new species Plate 11, fig. 6

Tooth small; bar thin, broad and slightly arched; anticusp relatively large and thin. Cusp laterally compressed, with a suggestion of sharp edges, acutely pointed and inclined to the bar at an angle of about 40 degrees. Denticles thin, sharp edged, broad at the base and rapidly tapering; alternating in size with one small denticle between the larger ones. Length, 1—1.3 mm.

Holotype.—Indiana University Paleontological Collection, No. 2259, lower New Albany shale, Locality 28, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 27, and 28.

Eurioniodina falx, new species Plate 11, fig. 9

Bar slender, rounded, and gently arched near the cusp; anticusp short, and rounded. Cusp slender, rounded, acutely pointed, and inclined to the bar at an angle of about 30 degrees. Denticles needle-like, and alternating in size with one or two small denticles between the larger ones. Cusp and denticles apparently inserted. Length, about 1 mm.

The species differs from *E. debilis* in having a more slender cusp, thinner denticles, and longer more nearly round bar.

Holotype.—Indiana University Paleontological Collection, No. 2292, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 27, and 28.

Genus SYNPRIONIODINA Ulrich and Brassler, 1926

Tooth consisting of cusp, denticulated bar and anticusp. The denticles on the anticusp are in the vertical plane of the bar and cusp. *Synprioniodina* differs from *Euprioniodina* in having the denticles closely appressed and joined by bar material; and the cusp is inclined upward rather than forward as in *Palmato-*

della. The anticusp in *Palmatodella* is longer than the anticusp in *Symprioniodina.*

Genoholotype.—*Synprioniodina alternata* Ulrich and Bassler, 1926. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Synprioniodina plana Holmes Plate 6, fig. 12; pl. 11, fig. 10

Synprioniodina plana Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 30, pl. 10, fig. 13. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Bar heavy, broad, flattened, and slightly bowed at the cusp; anticusp short, flattened, rounded on the convex side and with prominent escutchon on the concave side. Cusp short, broad, bluntly pointed, flattened with a suggestion of sharp edges, inclined forward at an angle of about 45 degrees; denticles on the bar, numerous, short, abruptly pointed, rounded and closely appressed, subequal in size except for a few small denticles between larger ones near the cusp; denticles on the anticusp more closely appressed than those on the bar but similar in shape; all denticles apparently inserted. Length, about 2.5 mm.

Plesiotypes.—Indiana University Paleontological Collection, No. 1928, upper New Albany shale, Locality 10, Rockford, Indiana; No. 1929, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 3, 10, and 14.

Synprioniodina newalbanyensis, new species Plate 6, fig. 18

Tooth small, bar thin, flattened and not bowed; anticusp short, flattened, and thin. Cusp short, acutely pointed, flattened, broad at the base and rapidly tapering; denticles closely spaced, apparently inserted, fused, and alternating near the cusp, becoming separated and having no alternation toward the end of the bar. No escutcheon. Length, about 1.3 mm.

Holotype.—Indiana University Paleontological Collection, No. 2322, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 3, 6, and 14.

Synprioniodina aclis, new species Plate 11, fig. 7

Tooth small, bar slender, laterally compressed, and slightly bowed near the cusp, anticusp short, flattened, and deflected more than a right angle. Cusp long, slender, laterally compressed, acutely pointed, and not inclined to the bar; denticles slender, rounded, acutely pointed, and separate, denticles on the bar curve toward the cusp, those on the anticusp are parallel to the cusp. Length of holotype, 1.4 mm.

Holotype.—Indiana University Paleontological Collection, No. 1933, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 3, and 10.

Synprioniodina decurrens, new species Plate 11, fig. 11

Bar slender, thin, laterally compressed, and slightly curved; anticusp broad, short, and carrying three or four small closely appressed, inserted denticles. Cusp large, broad at the base and gradually tapering, laterally compressed, and sharp edged; inclined to the bar at an angle of about 50 degrees. Denticles similar to the cusp in shape, and alternating in size with one or two small denticles between some of the larger ones. Length of holotype, 1.4 mm.

The species is similar to *S. alternata* Ulrich and Bassler, but differs in the inclination of the cusp, curvature of the bar, and the relative sizes of the alternating denticles. In *S. decurrens* the smaller set of denticles is extremely small and fine compared to the larger set of denticles.

Holotype.—Indiana University Paleontological Collection, No. 1927, New Albany shale, Locality 23, south of New Albany, Indiana.

Occurrence.—Rare in upper and middle New Albany shale at Localities 8, 19, and 23.

Genus PALMATODELLA Ulrich and Bassler, 1926

Bar slender and bent subcentrally so that the anticusp is nearly perpendicular to the posterior portion. Cusp and denticles fine, hair-like, usually closely appressed and inclined forward.

Genoholotype.—*Palmatodella delicatula* Ulrich and Bassler, 1926. Chattanooga shale, north-northeast of Huntsville, Alabama.

Palmatodella delicatula Ulrich and Bassler Plate 7, fig. 1

Palmatodella delicatula Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus. vol. 68, p. 41, pl. 10, fig. 5, text fig. 10 on p. 16. Chattanooga shale, 13 miles north-northeast of Huntsville, Alamaba. —Holmes in Butts, 1926, Geology of Alabama, Geol. Surv. Ala., special rept. 14, p. 160, pl. 48, fig. 13. Chattanooga shale, 4 miles west of New Market, Madison County, Alabama. —Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, art. 5, p. 29, pl. 10, fig. 10. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama. —Cooper, 1931, Jour. Paleon., vol. 5, p. 149, pl. 20, fig. 12. Lower part of Woodford, sec. 3, T. 2 N., R. 6 E., Oklahoma. —Bassler, 1932, Bull. 38, Tenn. Division of Geology, pl. 26, fig. 24. Ulrich and Bassler's figure republished.

Bar slender with the anticusp nearly perpendicular to the bar. Cusp broad at the base, acutely pointed, slightly inclined upward and directly forward. Denticles on the bar are short, sharp pointed, and well separated; anticusp denticles closely appressed, needle-like, and dimishing in size from a large one next to the cusp to a very minute one at the end of the anticusp. Length, about 1 mm.

The specimens from the New Albany shale referred to this species are most similar to those figured by Holmes from the Chattanooga shale, but are only about half as large as the Chattanooga specimens. Both the specimens figured by Holmes and the New Albany specimans are bent less than a right angle, and they both have three large denticles immediately anterior to the cusp. The holotype does not have the three larger anterior denticles, is bent more nearly a right angle and the cusp is less inclined upward than in the specimens figured by Holmes, and New Albany specimens. The specimen figured by Cooper from the lower part of the Woodford of Oklahoma, has very short anterior denticles and is probably a new species and not *Palmatodella delicatula.*

Plesiotype.—Indiana University Paleontological Collection, No. 1884, New Albany shale, Locality 23, south of New Albany. Indiana. Probably about 20 feet below Rockford limestone.

Occurrence.—Common in the middle New Albany shale at Localities 19, and 20; rare at Localities 18 and 23.

Palmatodella? paridens, new species Plate 11, fig. 3

Bar heavy, laterally compressed, and bent slightly more than a right angle. Cusp short, broad, laterally compressed, abruptly pointed, and directly forward in the plane of the bar, without upward inclination. Denticles numerous, subequal, laterally compressed, narrow, abruptly pointed, closely appressed, apparently deeply inserted and free only at the tips. On the bar the denticles are inclined toward the cusp; on the anticusp they are parallel to the cusp. Length, about 1.4 mm.

The species is referred to *Palmatodella* with some doubt, because of the heavy bar and arching more than a right angle. In *Telumodina* the arching is more than a right angle, but the species referred to this genus are extremely delicate and the denticles widely separated. It has seemed best to refer this new species to *Palmatodella* because of the closely appressed denticles.

Holotype.—Indiana University Paleontological Collection, No. 1885, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 3, 5, 6, and 14.

Genus METAPRIONIODUS, new genus

Bar heavy, rounded, usually with a distinct oral shoulder posterior to the cusp on the concave side; anterior portion deflected downward and curved laterally; posterior downward deflection always present. Cusp large, rounded, straight or slightly curved, and situated near the anterior end of the bar. Denticles separated and rounded with a few at the posterior end of the bar inclined nearly straight backward.

The genus differs from *Hindeodella* in the presence of a posterior downward projection; from *Angulodus* in having the cusp situated near the anterior end of the bar, and the denticles separated.

Genoholotype.—Metaprioniodus biangulatus, new species.

Metaprioniodus biangulatus, new species Plate 11, figs. 12, 13

Bar heavy, anterior portion bowed and deflected downward, posterior portion smoothly rounded on the convex side, and with a distinct oral shoulder on the concave side; posterior downward projection large and thinner than the rest of the bar. Cusp large, gently curved, rounded, and acutely pointed; denticles laterally compressed, with a suggestion of sharp edges, apparently not inserted, broad at the base and rapidly tapering, increasing in size from the cusp to the posterior downward projection with the exception of a few small denticles between the larger ones; 4 or 5 denticles on the anterior portion of the bar. Length, 2.3—2.9 mm.

The species differs from *M. fractus* in the shape of the cusp and denticles; and the larger posterior downward projection.

Holotype.—Indiana University Paleontological Collection, No. 1870; Paratype No. 1869, both types from the upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 3, 6, and 10.

Metaprioniodus fractus, new species Plate 11, figs. 14, 15

Bar thick, with the anterior portion deflected downward and strongly bowed; posterior portion rounded on the convex side and with distinct oral shoulder on the concave side; posterior downward projection small. Cusp rounded, gently curved and sharply pointed; denticles rounded, apparently not inserted, slender and increasing in size from the cusp toward the posterior end of the bar. Length, 1.2—2.3 mm.

The species differs from *M. biangulatus* in having more slender bar and denticles, and smaller posterior downward projection.

Holotype.—Indiana University Paleontological Collection, No. 1871; Paratype No. 1868, both types from the upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 3, and 10.

Genus LIGONODINA Ulrich and Bassler, 1926

Ligonodina Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, pp. 12-13. *Plagiodina* Cooper, 1933. Bull. Geol. Soc. Amer., vol. 44, p. 210. Branson and Mehl, 1933, Univ. of Missouri Studies, vol. 5, p. 48.

Conodonts with rounded cusp, denticulated bar and anticusp. The denticles on the anticusp are at right angles to the plane of the bar and cusp, and are inclined upward. The anticusp extends downward from one side of the cusp, and a deep groove extends from the tip of the anticusp on the undenticulate side to the end of the bar along the aboral side.

The essential characters of the genus are the lateral attachment of the anticusp and the fact that the denticles on the anticusp are at right angles to the plane of the bar and cusp. In *Euprioniodina* and *Synprioniodina* the denticles on the anticusp are in the same plane as the bar and cusp. In *Hindeodelloides* the denticles on the anticusp are at some angle to the plane of the bar and cusp, and may be at right angles; but the genus is distinguished from *Ligonodina* by the central attachment of the anticusp, and lack of groove on the undenticulated side.

Genoholotype.—Ligonodina pectinata Ulrich and Bassler, 1926. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Ulrich and Bassler in their description of *Ligonodina* misinterpreted the denticles on the anticusp, and degarded them as "suckerlike impressions". Because these denticles are at right angles to the plane of the bar and cusp they are usually broken off when this side of the tooth is exposed; these broken denticles give the appearance of "suckerlike impressions" noticed and described by Ulrich and Bassler.

Cooper[39], 1933, first showed that the "suckerlike impressions" of *Ligonodina* are merely broken denticles. He proposed the name *Plagiodina* to include species described under *Ligonodina, Euprioniodina* and *Prioniodus,* having denticulated anticusps with the denticles perpendicular to the plane of the bar and cusp. A strict interpretation of the International Rules of Zoological Nomenclature amendment[40] to Article 25, Section c, 3 would make *Plagiodina* unavailable because Cooper designated no genotype. Moreover, Cooper[41] finds by a study of topotype material that *Ligonodina pectinata,* the genoholotype of *Ligonodina,* has denticles on the anticusp at right angles to the plane of the bar and cusp; and since the genoholotype and not the original description determines the characters of a genus, *Ligonodina* must be redefined as above and *Plagiodina* Cooper is a synonym of *Ligonodina.*

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[39] Cooper, C. L., 1933. Revision on **Ligonodina** Ulrich and Bassler, and **Prioniodus** Pander, 1856. Bull. Geol. Soc. Amer., vol. 44, p. 210.

[40] Science, 1928, New Series, vol. 67, pp. 17-18.

[41] Personal communication.

Branson and Mehl[42], 1933, also came to the conclusion that the "suckerlike impressions" of Ulrich and Bassler are really broken denticles.

Ligonodina species Plate 7, fig. 8

Bar heavy and rounded, anticusp unknown; cusp large, nearly straight, and ovate in cross section; denticles rounded, separate, and increasing in size toward the posterior end of the bar without alternation.

Figured specimen, Indiana University Paleontological Collection, No. 2253, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Ligonodina species Plate 7, fig. 11

Bar heavy, rounded, and gently curved; anticusp unknown; cusp rounded, erect, and nearly straight; denticles numerous, rounded, and alternating with 2 or 3 small denticles between the larger ones.

The figured specimen probably represents a new species, but it has seemed best not to name it until specimens with the anticusp are found.

Figured specimen, Indiana University Paleontological Collection, No. 2278, upper New Albany shale, Locality 8, east of Vienna, Indiana.

Ligonodina hindei Ulrich and Bassler
Plate 7, figs. 13, 22; pl. 12, figs. 13, 14 text fig. 3, no. 5

Ligonodina hindei Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol 68, p. 14, pl. 2, figs. 14, 15, 16. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Bar thick, straight or slightly curved; anticusp large, curved toward the posterior end of the bar, and carrying five denticles. Cusp long, gently curved, rounded near the base and becoming flattened and somewhat sharp edged near the tip. Denticles on the bar rounded, inclined, and sharply curved near the base; seven in number. The specimen shown in Plate 7, figure 13 is considerably smaller, has a thinner bar, and less curved anticusp than the others placed in the species and is therefore doubtfully referred here. Length, about 2.5 mm.

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[42] Branson and Mehl, 1933, Univ. of Missouri Studies, vol. 8, p. 48.

Plesiotypes.—Indiana University Paleontological Collection, Nos. 2255, 2309, 2310, lower New Albany shale, Locality 32, Prather, Indiana. No. 1886, lower New Albany shale, Locality 30, Prather, Indiana.

Occurrence.—Common in the lower New Albany shale at Locality 26, rare at Localities 30, 32, and 33.

Ligonodina pinguis (Hibbard)? Plate 7, fig. 14

Prioniodus pinguis Hibbard, 1927, Amer. Jour. Sci., 5th ser., vol. 13, p. 193, fig. 2c. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Bar short, thick, and gently curved; cusp long, acutely pointed, gently curved and ovate in cross section; denticles similar to the cusp in shape, separated, inclined and curved toward the posterior end of the bar.

The anticusp was not described by Hibbard. In the New Albany specimens doubtfully referred to the species the anticusp is short, thin, and carries 3 or 4 denticles. Although specimens are common at one locality and rare at several others in the New Albany shale, no perfect specimen has been found, and the posterior portion of the bar may be considerably longer. The holotype appears to be complete, and for this reason the New Albany specimens are referred doubtfully to the species.

Plesiotype.—Indiana University Paleontological Collection, No. 1931, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Common in the upper New Albany shale at Locality 3, rare at Localities 1, 2, 4, 8, 10, and 14.

Ligonodina species Plate 7, fig. 18

Bar laterally compressed, rounded, and slightly curved; anticusp short, with 3 closely spaced denticles; cusp rounded and curved; denticles laterally compressed, rounded, and alternating with 2 or 3 small denticles, between the larger ones.

Known from a single broken specimen.

Indiana University Paleontological Collection, No. 1792, upper New Albany shale, Locality 2, southwest of Henryville, Indiana.

Ligonodina species Plate 7, fig. 19

Bar rounded, length and curvature unknown; anticusp long, slender, and gently curved, with 4 or 5 rounded denticles. Cusp rounded and curved; denticles rounded, separate, and apparently alternating.

Figured specimen, Indiana University Paleontological Collection, No. 1794, upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, and 10.

Ligonodina species Plate 12, fig. 8

Bar thin, long, and nearly straight; anticusp short and thin with probably 3 denticles; cusp long, slender, and gently curved; denticles short, separated, laterally compressed, and rounded.

Differs from *L. conidens* in having shorter denticles, longer cusp, and thinner anticusp. Known from a single specimen.

Figured specimen, Indiana University Paleontological Collection, No. 2273, upper New Albany shale, Locality 1, New Albany, Indiana.

Ligonodina bicincta, new species Plate 12, fig. 15

Bar flattened, relatively thin, and slightly curved; anticusp of moderate length, thin, and carries 4 or 5 rounded denticles; cusp long slender, rounded, and curved near the base; denticles needle-like, and alternating near the posterior end of the bar with one small denticle between the larger ones. Length, about 2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2279, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Ligonodina cryptodens, new species Plate 12, figs. 16, 17

Bar flattened, moderately thick, and gently curved; anticusp long, carrying 7 rounded denticles; cusp rounded, and probably gently curved; denticles rounded, slender; with one small denticle between some of the larger ones. Length of holotype, 2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2277, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 27 and 28.

Ligonodina conidens, new species Plate 12, figs. 18, 19

Bar laterally compressed and somewhat rounded, nearly straight, and rather short; anticusp small, short, thick and carries 4 or 5 short, closely spaced denticles. Cusp rounded and gently curved; denticles slender, and rounded. Posterior end of the bar unknown.

Holotype.—Indiana University Paleontological Collection, No. 2334, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper part of the New Albany shale at Localities 1, 3, 5, 6, 8, and 10.

Ligonodina arcuata, new species Plate 12, figs. 20, 21; text fig. 3, no. 4

Bar flattened, relatively thin, gently curved, and deflected at the posterior end; anticusp of moderate length, thick, and carrying 5 denticles. Cusp rounded, slender, and apparently straight. Denticles rounded, separated, and irregular in size and shape; broader ones laterally compressed. Some specimens have considerably longer denticles near the posterior end of the bar. Length of holotype, 2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2276, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 27 and 28.

Family PRIONIODINIDÆ Ulrich and Bassler, 1926

Conodonts with denticulated bar, with or without cusp; cusp, if present, situated in the median third of the bar.

Genus PRIONIODINA Ulrich and Bassler, 1926

Bar more or less arched and crowned with numerous, rounded, subparallel, and separated denticles. Cusp rounded and located in the median third of the bar. Escutcheon present.

The genus differs from *Prioniodella* in having a cusp, from *Bryantodus* by the separated denticles, and from *Lonchodina* by the lack of strong outward bowing of the bar.

Genoholotype.—*Prioniodina subcurvata* Ulrich and Bassler, 1926. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Prioniodina separans Holmes Plate 1, fig. 7

Prioniodina separans Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 27, pl. 9, figs. 16, 17. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Bar rather slender, long, rounded and strongly arched upward; cusp developed at the point of curvature, ovate in cross section, inclined and gently curving; denticles numerous, 14 or more in number, similar to the cusp in shape, and rather short. Both the denticles and cusp curve inward toward the concave side of the bar. Escutcheon prominent on the concave side of the bar. Length, about 2 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1896, upper New Albany shale, Locality 11, north of Henryville, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 3, 5, 11, and 14.

Prioniodina acicularis, new species Plate 1, fig. 8

Bar of medium weight and sharply arched at a point about one-third the length of the bar from the posterior end; cusp laterally compressed, ovate in cross section, and gradually tapering; denticles numerous, and similar to the cusp in shape and inclination. Posterior denticles alternating in size; but the anterior denticles do not alternate and are somewhat larger than the posterior ones. Escutcheon small. Length of holotype, about 2.1 mm.

Holotype.—Indiana University Paleontological Collection, No. 1934, upper New Albany shale, Locality 9, north of Rockford, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 9, and 11.

Prioniodina curta, new species Plate 4, fig. 13

Bar relatively short, rounded, and moderately arched; cusp large, rounded and gradually tapering; denticles few, about five posterior and six anterior, anterior ones longer than posterior, all relatively short, rounded, broad at base and rapidly tapering; escutcheon prominent but not expanded below. Length of holotype, 1.5 mm.

Holotype.—Indiana University Paleontological Collection, No. 2316, lower New Albany shale, Locality 32, Prather, Indiana.

Occurrence.—Rare in lower New Albany shale at Locality 32.

Prioniodina arrecta, new species Plate 4, fig. 14

Bar short, rather thin, slightly rounded, and nearly straight; cusp rounded, gradually tapering, and slightly inclined; denticles few, 5 to 7 on each side of the cusp, separated, with no indication of insertion of either the denticles or cusp; escutcheon prominent and expanded at the base. Length of holotype, 1.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2261, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Prioniodina subrecta, new species Plate 6, fig. 1

Bar heavy, rounded and moderately arched; cusp nearly erect, subcentral, rounded, and gradually tapering; denticles large, separated, gradually tapering and rounded; escutcheon small. Length, about 2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2328, upper New Albany shale, Locality 2, southwest of Henryville, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 2, 13, and 14.

Genus PRIONIODELLA Ulrich and Bassler, 1926

Conodonts with short, straight or slightly arched bar; denticles subequal apparently inserted, and without distinguishable cusp. Denticles separate and more or less closly spaced. Differs from *Bryantodus,* and *Prioniodina* in the lack of a cusp.

Genoholotype.—Prioniodella normalis Ulrich and Bassler, 1926. Rhinestreet shale (Upper Devonian, Portage), Shaleton New York.

Prioniodella cunea, new species Plate 1, fig. 9

Bar heavy, laterally compressed and nearly straight; denticles numerous, 16 to 18, rounded, slender, abruptly pointed, closely appressed, and varying considerably in size; escutcheon present. Length of holotype, 2.1 mm.

The species is characterized by its large size, and closely appressed and unequal denticles.

Holotype.—Indiana University Paleontological Collection, No. 1926, upper New Albany shale, Locality 2, southwest of Henryville, Indiana.

Occurrence.—Rare in the upper part of the New Albany shale at Localities 2, 3, 6, 8, and 9.

Prioniodella ordinata, new species Plate 1, fig. 10

Bar short, laterally compressed, narrow, and straight; denticles numerous, 14 or more in number, slender, laterally compressed, closely spaced, inserted and decreasing in size from the center toward both ends of the bar; escutcheon present and situated subcentrally. Length of holotype, 1 mm.

The species differs from *P. informata* Ulrich and Bassler and *P. brevispina* Ulrich and Bassler in having a narrow bar, long, slender denticles, and an escutcheon. *P. ordinata* also has more closely spaced denticles than either of the above mentioned species.

Holotype.—Indiana University Paleontological Collection, No. 1897, middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Rare in the middle part of the New Albany shale at Localities 18, 19, and 20.

Prioniodella cristula, new species Plate 1, fig. 11

Bar rather heavy, laterally compressed, and slightly bent near the middle; no cusp distinguishable, but the median denticles somewhat larger than those near the ends of the bar. Denticles about 24 in number, long, slender, deeply inserted, closly spaced, rounded and slightly compressed laterally. No escutcheon noted, and probably not present. Length, about 1.6 mm.

The bar of this species is longer and more abruptly bent than in other species of this genus.

Holotype.—Indiana University Paleontological Collection, No. 2257, middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Rare in the middle part of the New Albany shale at Localities 18, and 20.

Genus BRYANTODUS Ulrich and Bassler, 1926

The genus is characterized by distinct cusp, and laterally confluent, sharp edged denticles. Usually the base forms a narrow flange-like expansion on both sides, and there is an escutcheon or downward projection beneath the cusp.

Genoholotype.—*Bryantodus typicus* Ulrich and Bassler, 1926. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Bryantodus cognatus, new species Plate 1, fig. 12; pl. 4, fig. 10

Bar heavy, laterally compressed, and slightly arched; cusp subcentral, inclined, broad at base and gradually tapering; denticles closely appressed, apparently inserted, 9 to 11 anterior, and 12 to 14 posterior; escutcheon small; strong lateral ridge or elongate node extending from the base of the cusp less than half the length of the anterior portion of the bar. Length, 1.2-2 mm.

Differs from *B. nitidus* Ulrich and Bassler in the less marked arching and short lateral ridge.

Holotype.—Indiana University Paleontological Collection, No. 2350; Paratype No. 1826, both types from middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 18, 19, and 20.

Bryantodus multidens Ulrich and Bassler Plate 2, figs. 1-3

Bryantodus multidens Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 22, pl. 6, figs. 15, 16. Rhinestreet shale (Portage, Upper Devonian), Shaleton, New York.

Bar heavy, rounded, and gently arched upward; cusp short, laterally compressed, and abruptly pointed; denticles numerous, closely spaced, ovate in cross section, short, abruptly pointed, and apparently inserted. Large lateral, rounded flanges extend the whole length of the bar on both sides; escutcheon present. Length , 1.2-2.2 mm.

B. multidens is characterized by the short cusp, numerous, short denticles and the strong lateral flanges on both sides of the bar. *B. brevidens* has greater upward arching than *B multidens,* and lacks the flange on the convex side.

Plesiotypes.—Indiana University Paleontelogical Collection, Nos. 1815, 1816, 1856, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 26, 27, 28, 32, and 33.

Bryantodus pergracilis, Ulrich and Bassler Plate 2, fig. 4

Bryantodus pergracilis Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 27, pl. 10, fig. 11. Hardin sandstone, Mount Pleasant, Tennesee.

Bar flat, thin, and nearly straight; cusp subcentral, short, flattened, sharp-edged,, and acutely pointed; denticles similar to the cusp in shape, numerous, slightly separated, and decreasing in size toward the ends of the bar; escutcheon small. Length, about 1 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1827, upper New Albany shale, Locality 11, north of Henryville, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 3, 9, 11, and 13.

Bryantodus subbrevis Ulrich and Bassler Plate 2, fig. 5

Bryantodus subbrevis Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 28, pl. 10, figs. 15, 16. Hardin sandstone, Mount Pleasant, Tennessee.

Tooth semiovate in outline; bar thin, broad with slightly curved base; cusp and denticles inclined, flattened, sharp-edged, abruptly pointed and apparently inserted; escutcheon small. Length, about 0.5 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1825, upper New Albany shale, Locality 14, southeast of Henryville, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, and 14.

Bryantodus camurus, new species Plate 2, figs. 6-9

Bar short, broad, thin, curved laterally in the posterior portion, and gently arched subcentrally; cusp broad, abruptly pointed, sharp-edged, and situated about one-third of the distance from the posterior end of the bar, usually more or less fused with the adjacent denticles. Denticles short, flattened, abruptly pointed and decreasing in size toward the posterior end of the bar. Near the anterior end there is a group of 3 or 4 larger denticles, and the rounded anterior end of the bar is denticulate. A thin lateral keel extends nearly the full length of the bar on both sides. Escutcheon small. The specimen illustrated on Plate 2, figure 9, represents an extreme variation in which the cusp is reduced in size. Length of holotype, 1.2 mm.

The species is characterized by the posterior curve of the bar, the thin lateral keels, and the short, broad bar.

Holotype.—Indiana University Pateontological Collection, No. 1805, upper New Albany shale, Locality 8, southeast of Vienna, Indiana. Paratypes Nos. 1806, 1807, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.— Upper New Albany shale; abundant at Locality 2, common at Localities 1, 3, 6, and 8; rare at Localities 5, 9, and 10.

Bryantodus microdens, new species Plate 2, fig. 10

Tooth small, nearly as broad as long; bar short, and thin with straight base; cusp distinct but not prominent; both cusp and denticles laterally compressed, abruptly pointed, and closely appressed with the inserted part wedge-shaped and with narrow grooves between denticles; escutcheon small; a strong, straight lateral ridge extends nearly the full length of the bar. Length of holotype, 0.8 mm.

Holotype.— Indiana University Paleontological Collection, No. 1819, upper New Albany shale, Locality 6, north of New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 3, 6, and 14.

Bryantodus pectenellus, new species Plate 2, fig. 11

Bar short, laterally compressed, with posterior end deflected downward; both cusp and denticles short, abruptly pointed, closely appressed, and apparently inserted; escutcheon small; a low lateral ridge on the anterior portion of the bar. Length of holotype, 0.9 mm.

Holotype.—Indiana University Paleontological Collection, No. 1820, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale at Locality 26.

Bryantodus flexus, new species Plate 2, fig. 12

Tooth small; bar thin, slightly arched, laterally bowed, and the posterior end bent; cusp relatively short, broad at the base, acutely pointed, and difficult to distinguish from a large posterior denticle which is separated from the cusp by a single smaller denticle; denticles short, closely appressed, apparently inserted, with about 10 on each side of the cusp; escutcheon small. Length of holotype, 0.9 mm.

Species characterized by the small size, arching and lateral bowing.

Holotype.—Indiana University Paleontological Collection, No. 1814, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 27 and 28.

Bryantodus commutatus, new species Plate 2, figs. 13, 14

Bar slightly arched, heavy and rounded anteriorly, but thin and flat posteriorly; cusp short, inclined, sharp-edged, and situated about one-third of the length of bar from posterior end; denticles similar in shape and inclination to the cusp, apparently more deeply inserted near the cusp; anterior ones about 11 in number, larger and more fused than those posterior to cusp, about 6 in number; escutcheon small. Length of holotype, 1.3 mm.

B. commutatus is similar to *B. nitidus* U. and B., but the arching of the bar is much less and there are fewer denticles posterior to the cusp. It may be identical with the specimen figured on Plate 4, figure 14 by Ulrich and Bassler[43] which they referred doubtfully to *B. nitidus.*

Holotype.—Indiana University Paleontological Collection, No. 1809; Paratype No. 1810, both types lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Lower New Albany shale; abundant at Localities 27, and 28; rare at Localities 29, 30, and 31.

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[43] Proc. U. S. Nat. Mus., vol. 68.

Bryantodus concavus, new species Plate 2, fig. 15-17

Bar broad, laterally compressed, and strongly arched; cusp in median third, sharp edged, and acutely pointed; denticles similar to the cusp in shape and inclination, decreasing in size toward the ends of the bar, apparently inserted, 8 to 10 anterior, and 10 to 12 posterior; escutcheon small. Length of holotype, 1.2 mm.

Holotype.— Indiana University Paleontological Collection, No. 1811; Paratypes Nos. 1812, 1813. All types from the lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence—Lower New Albany shale, common at Localities 27 and 28; rare at Localities 29 and 30.

Bryantodus serrula, new species Plate 2, figs. 18-20

Bar relatively short, broad, laterally compressed, straight or slightly arched; cusp subcentral, flattened, sharp-edged and gradually tapering, varying considerably in width and relative closeness of spacing; total number of denticles varies from 16 to 18; escutcheon small. Length, 1.2-1.5 mm.

B. serrula differs from *B. inequalis* Holmes in having a nearly straight bar, and denticles subequal on the two sides of the cusp.

Holotype.—Indiana University Paleontological Collection, No. 1821. Paratype No. 1822, upper New Albany shale, Locality 1, New Albany, Indiana. Paratype No. 1823, upper New Albany shale, Locality 14; southeast of Henryville, Indiana.

Occurrence.—Common in the upper part of New Albany shale. Abundant at Localities 1 and 3, common at Localities 6, 8, 10, and 11, rare at Localities 9, 12, 13, and 14.

Bryantodus plenus, new species Plate 2, fig. 21

Bar massive, rounded, laterally bowed posterior to the cusp, and slightly arched; cusp not much longer than denticles, broad at base and acutely pointed; denticles closely spaced, sharp-edged, and apparently inserted, 7 anterior and 9 posterior on the holotype; escutcheon small; no lateral ridge. Length of holotype, 2 mm.

Holotype—Indiana University Paleontological Collection, No. 2305, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence—Rare in middle New Albany shale at Locality 20.

Bryantodus brevidens, new species Plate 3, figs. 1, 2

Bar heavy, rounded, and abruptly arched below the cusp; cusp subcentral, sharp-edged, broad at the base and rapidly tapering; denticles closely appressed, short, sharp-edged, broad at the base and rapidly tapering, 8 to 10 on each side of the cusp with no indication of insertion; escutcheon small; a strong, smooth, lateral ridge extends the full length of the bar on the one side, and a low ridge on the anterior portion of the bar on the other side. Length of holotype, 1.2 mm.

The species is similar to *B. multidens* Ulrich and Bassler, but differs in having shorter denticles and greater arching of the bar.

Holotype.—Indiana University Paleontological Collection, No. 1803; Paratype No. 1804, both types from upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare at Localities 1, 2, 3, 8, 9, 10, 11, and 14.

Bryantodus cf. **germanus** Holmes Plate 3, fig. 5

Bryantodus germanus Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 28, pl. 10, fig. 5. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Bar broad, laterally compressed with base nearly straight; cusp subcentral, inclined, moderately curved, broad at the base and bluntly pointed; denticles apparently inserted, 7 to 9 on each side of the cusp, closely appressed, abruptly pointed, and laterally compressed; no escutcheon seen. Length, about 1.4 mm.

Pleisotype.—Indiana University Paleontological Collection, No. 1817, upper New Albany shale, Locality 1, New Albany, Indiana.

Ocurrence.—Very rare in the upper New Albany shale at Locality 1.

Bryantodus coalescenoides, new species Plate 3, fig. 8

Bar heavy, flattened, and gently arched; cusp subcentral, broad, abruptly pointed, flattened and joined with two or three adjacent denticles by bar material. Denticles similar in shape to the cusp and are likewise joined; exact number not known, but at least 5 posterior and 5 anterior present. Length of holotype, about 1.8 mm.

B. coalescenoides differs from *B. coalescens* Ulrich and Bassler in the small amount of curving of the bar, and seems to have more denticles.

Holotype.—Indiana University Paleontological Collection, No. 1808, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare at Locality 26.

Bryantodus notatus, new species Plate 4, figs. 1, 2

Bar heavy, long, laterally compressed, and slightly arched; cusp subcentral, rounded, and gradually tapering; denticles closely appressed, sharp-edged, long, slender, and acutely pointed, about 10 anterior denticles with no alternation, and about 14 large posterior denticles with smaller denticles between the larger ones apparently inserted or buried in bar material, all denticles apparently inserted; excutcheon small. Length, about 2.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2304; Paratype No. 2303 both types from the middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 20, and 21.

Bryantodus incisus, new species Plate 4, figs. 3, 4

Bar short, and rather massive with nearly straight base; cusp broad, blunt and fused with the adjacent denticles by clear material extending beyond the end of the cusp; denticles short, sharp-edged, closely appressed, inserted and fused, with some completely buried; escutcheon small; strong lateral ridges extending nearly the full length of the bar on both sides. Length of holotype, 1.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2300, lower New Albany shale, Locality 26, north of Speed, Indiana.

Ocurrence.—Rare in lower New Albany shale at Localities 26, 28, and 32.

Bryantodus subplanus, new species Plate 4, figs. 5, 6

Bar short, extremely broad, very thin and slightly arched and bowed; cusp acutely pointed, laterally compressed and sharp-edged; denticles closely appressed, thin, sharp-edged and deeply inserted; anterior denticles curve toward the cusp and the posterior denticles are inclined parallel to the cusp. A group of denticles near the posterior end are larger than the rest. No escutcheon nor lateral ridge.

There are 12 anterior and 11 posterior denticles on the holotype (fig. 5), but only 6 anterior and 14 posterior denticles on the paratype (fig. 6). The latter may have the anterior end broken off, but it does not appear broken. Length of holotype, 1.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2265, middle New Albany shale, Locality 20, north of New Albany, Indiana. Paratype No. 2312, middle New Albany shale, Locality 19, southeast of Henryville, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 18, 20, and 21.

Bryantodus subcarinatus, new species Plate 4, figs. 7, 8

Bar moderately heavy, rounded, and strongly arched below the cusp; cusp subcentral, rounded, and acutely pointed; denticles numerous 22 to 26, rounded, anterior ones abruptly pointed, posterior more slender and acutely pointed, all closely appressed, but apparently not inserted; escutcheon small; lateral ridge prominent on the anterior portion of the bar on both sides. Length of holotype, 1.4 mm.

Holotype.—Indiana University Paleontological Collection, No. 2348; Paratype No. 2349, both types from middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in middle New Albany shale at Localities 18, 20, and 21.

Bryantodus parvus, new species Plate 4, fig. 9

Tooth small, bar short, thin and slightly arched; cusp subcentral, flattened, sharp edged and acutely pointed; denticles closely appressed and similar to the cusp in shape, inclination and apparent insertion, 9 to 12 on each side of the cusp; escutcheon small and thin. Length of holotype, 0.8 mm.

B. parvus is similar to *B. inequalis* Holmes but differs in that the tooth is smaller, thinner, and the denticles are subequal.

Holotype.—Indiana University Paleontological Collection, No. 2351, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20; common in upper New Albany shale at Localities 1, 3, 6, 8, and 10.

Bryantodus mirus, new species Plate 4, fig. 11

Bar short, laterally compressed, rather thin, with posterior end deflected downward; cusp subcentral, rounded, and acutely pointed; denticles closely appressed, apparently inserted, acutely pointed, 8 to 10 on each side of the cusp; escutcheon small; low lateral ridge on the anterior portion of the bar. Length of holotype, 1.2 mm.

Differs from *B. serrula* in having the posterior portion deflected downward.

Holotype.—Indiana University Paleontological Collection, No. 2302, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Bryantodus nodus, new species Plate 4, fig. 12

Bar short, laterally compressed, and slightly arched; cusp about three times as broad as the largest denticle, short, abruptly pointed, and situated subcentrally; denticles closely appressed, sharp-edged, short, abruptly pointed, about 10 on each side of cusp, and decreasing in size toward the ends of the bar; escutcheon small if present; prominent three sided node developed on the side of the bar below the cusp. Length of holotype, 1.4 mm.

Species somewhat similar to *B. nitidus* Ulrich and Bassler but differs in having a broader bar with less arching, and fewer denticles.

Holotype.—Indiana University Paleontological Collection, No. 1818, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Locality 1.

Bryantodus planus, new species Plate 10, fig. 8

Bar short, slightly arched, laterally compressed, and very thin; cusp short, broad at the base, acutely pointed, and situated slightly anterior to the escutcheon; denticles similar in shape to the cusp with usually 4 anterior and 6 posterior. The cusp and the denticles are both extremely flattened, and apparently inserted. Escutcheon rather small. Length of holotype, 0.9 mm.

The denticles in this species are separated more than is usual in *Bryantodus,* but the flattening seems to relate the species more closely to *Bryantodus* than to *Prioniodina,* which the spacing of the denticles somewhat suggests.

Holotype.—Indiana University Paleontological Collection, No. 1932, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Locality 1.

Bryantodus aplatus, new species Plate 10, fig. 11

Bar heavy, nearly straight except for the posterior end which is slightly bent downward. Cusp rounded, straight, and sharply pointed. Denticles rounded, closely appressed, sharply pointed, and apparently not inserted. Escutcheon small. Length of holotype, 1.8 mm.

Holotype.—Indiana University Paleontological Collection, No. 2329, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 32, and 33.

Genus ANGULODUS, new genus

Bar heavy, rounded, with both the anterior and posterior ends deflected downward; anterior end curved laterally. Cusp subcentral, rounded and straight or slightly curved; denticles closely spaced, rounded, and apparently inserted; a few denticles at the posterior end of the bar point straight backward; denticles usually increase in size from the cusp to the posterior end of the bar.

The genus differs from *Metaprioniodus* in the apparent insertion and close appression of the denticles, and the subcentral position of the cusp; from *Bryantodus* in the lack of lateral ridges and possession of posterior downward projection.

Genoholotype.—Angulodus demissus, new species.

Angulodus demissus, new species Plate 10, fig. 15

Bar heavy, rounded, with oral shoulder on concave side posterior to cusp, anterior portion deflected downward and slightly bowed laterally; posterior projection small. Cusp rounded, length unknown; denticles rounded, closely spaced, and apparently inserted. Length of holotype, 1.8 mm.

Holotype.—Indiana University Paleontological Collection, No. 2341, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 27, and 28.

Angulodus gravis, new species Plate 3, figs. 3, 4

Bar massive, laterally compressed, with posterior and anterior downward projections; cusp slightly rounded on the one side, and flattened on the other side, sharp-edged, broad at the base and gradually tapering; denticles numerous, 8 to 10 anterior and 35 to 40 posterior, closely appressed, sharp-edged, apparently inserted with the posterior denticles alternating in size, one small one between the larger, no alternation of anterior denticles; no escutcheon or flange. Length of holotype, 1.8 mm.

Holotype.—Indiana University Paleontological Collection, No. 1873, Paratype, No. 1874, both types from the middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 20 and 21.

Angolodus walrathi (Hibbard) Plate 4, fig. 15; plate 10, fig. 5

Hindeodella walrathi Hibbard, 1927, Amer. Jour. Sci., 5th ser., vol. 13, p. 205, figs. 4a, 4b. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Bar heavy, short and laterally compressed with the anterior portion deflected downward and slightly curved inward; posterior end of bar abruptly deflected downward to form a hook. Cusp subcentral, small, laterally compressed, and gradually tapering. Denticles similar to the cusp in shape and inclination except on the posterior "hook" where a few denticles point backward in the plane of the bar; all denticles apparently inserted, and alternating, with one to three small denticles between the larger ones. Length, about 1.8 mm.

Specimens from the New Albany shale agree well with the cotypes except that the denticles seem to be more closely spaced.

Plesiotypes.—Indiana University Paleontological Collection, No. 2338, 2339, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities, 1, 2, 3, 6, 8, and 10.

Angolodus spissus, new species Plate 10, fig. 7

Bar heavy, with oral shoulder on concave side posterior to cusp; sharply bowed laterally and deflected downward in the anterior portion so that the denticles on this part of the bar are in a plane perpendicular to the plane of the cusp and posterior portion of the bar; posterior downward projection small. Cusp large, rounded and slightly inclined; denticles closely appressed, apparently inserted, sharply pointed, laterally compressed, and tend to be sharp-edged near the tips. Length of holotype, 2.2 mm.

The species differs from other species in the genus in having the anterior portion of the bar more sharply bowed and strongly deflected downward.

Holotype.—Indiana University Paleontological Collection, No. 2286, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Genus HIBBARDELLA Ulrich and Bassler, 1926

Tooth bilaterally symetrical with large, central, erect, cusp. Bar moderately heavy, and more or less arched. Denticles separated, curve inward, and usually few in number.

Genoholotype.—*Hibbardella angulata* (Hinde), 1879. Genessee (Upper Devonian) North Evans, New York.

Hibbardella angulata (Hinde) Plate 3, figs. 6, 7; plate 10, fig. 12

Prioniodus angulatus Hinde, 1879, Quart. Journ. Geol. Soc. London, vol. 35, p. 360, pl. 15, fig. 17. Genesee (Upper Devonian) North Evans, New York.

Hibbardella angulata Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., 18 mile Creek and Shaleton, New York. Branson and Mehl, 1933, vol. 68, p. 37, pl. 3, figs. 1-4. Rhinestreet shale (Devonian, Portage), Univ. of Missouri Studies, vol. 8, p. 141, pl. 11, fig. 16, new figure of holotype.

Bar rounded and arched 80 to 90 degrees at the median point; cusp central, erect, rounded, sides nearly parallel; denticles well separated, usually five on either side of cusp. Height, 1-2 mm.

Plesiotypes.—Indiana University Paleontological Collection, No. 1835, lower New Albany shale, Locality 27, Chelsa, Indiana; No. 1836, upper New Albany shale, Locality 9, north of Rockford, Indiana; No. 2293, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare throughout the New Albany shale at Localities 2, 6, 8, 9, 10, 13, 14, 20, 26, 27, 30, and 31.

Hibbardella symmetrica, new species Plate 3, fig. 9

Bar slightly curved, laterally compressed, broad at ends and narrowing toward the cusp, central portion near the cusp bowed outward. Cusp narrow, parallel sided and curving inward. Denticles needle-like and alternating, with 1 to 3 small ones between the larger ones; larger denticles rounded, gradually tapering, subequal and curved toward the cusp. Length of holotype, 1.8 mm.

The species is similar to *H. subgrandis* Hibbard, but differs in having alternating denticles.

Holotype.—Indiana University Paleontological Collection, No. 1839, upper New Albany shale, Locality 2, southwest of Henryville, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 2, 9, 10, 13, and 14.

Hibbardella? telum, new species Plate 3, figs. 10-12

Bar heavy and sharply arched so that the whole tooth has a subtriangular outline; cusp short, broad at base and gradually tapering, laterally compressed, and sharp-edged; denticles rounded, acutely pointed, closely appressed, fused, and apparently deeply inserted, 8 to 10 on each side of the cusp; no escutcheon. Height, 1.2-1.5 mm.

Holotype.—Indiana University Paleontological Collection, No. 2251, middle New Albany shale, Locality 20, north of New Albany, Indiana. Paratype No. 1840, upper New Albany shale, Locality 1, New Albany, Indiana. Paratype No. 1841, lower New

Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare throughout the New Albany shale at Localities 1, 10, 13, 20, 27, and 28.

Hibbardella pandata, new species Plate 3, fig. 13

Tooth large with bar of medium weight, rounded, bowed and arched, with the base of the cusp at the center of both curvatures. Cusp long, parallel-sided, rounded, curved inward, and tip rounded. Denticles similar in shape to the cusp, separated by their own diameter or more; usually 8 on each side of cusp. Height, about 3 mm.

The species is characterized by the large cusp and strong bowing and arching of the bar. It differs from *H. curvata* Holmes in having more denticles and a greater angle of divergence of the two sides of the symmetrical bar.

Good specimens are rare in the New Albany shale, but fragments are abundant and easily recognized by the large cusp.

Holotype.—Indiana University Paleontological Collection, No. 1898, lower New Albany shale, Locality 32, Prather, Indiana.

Occurrence.—Abundant in the lower part of the New Albany shale at Locality 32; common at Locality 26.

Hibbardella distans, new species Plate 3, fig. 14

Bar light, laterally compressed and slightly arched; cusp elongate, gradually tapering, rounded and bowed inward, this bowing occurs near the base and involves the bar; denticles slender, acutely pointed, separated, and not inserted; no escutcheon. Height, about 1.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 2258, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Hibbardella insignis, new species Plate 3, fig. 15

Bar short, laterally compressed, and moderately arched; cusp extremely long, and rather thick with sharp edges perpendicular to the plane of bar and cusp; denticles closely spaced, alternating in size, rounded, acutely pointed, and apparently inserted; no escutcheon. Height of holotype, 1.7 mm.

Holotype.—Indiana University Paleontological Collection, No. 2252, upper New Albany shale, Locality 8, east of Vienna, Indiana.

Occurrence.—Rare in upper New Albany shale at Localities 1, 3, 8, 10, 13, and 14.

Hibbardella? divergens, new species Plate 10, fig. 6

Bar thin, laterally compressed, arched to form a flaring *V*, open aborally; cusp short, sharp-edged, and gradually tapering; denticles 10 to 12 on each side of the cusp, short, closely spaced, sharp-edged and inserted. Height of holotype, 0.7 mm.

H. divergens is distinguished by the flaring *V*, shape of the bar, short cusp and numerous closely spaced denticles.

Holotype.—Indiana University Paleontological Collection, No. 1837, upper New Albany shale, Locality 13, south of Henryville, Indiana.

Occurrence.—Rare in the upper part of the New Albany shale at Localities 1, 3, 8, and 13.

Genus LONCHODINA Ulrich and Bassler, 1926

Bar heavy and rounded, with the two ends nearly equal in length and the whole bar arched and bowed. Cusp not always distinguishable. Denticles rounded, needle-like, unsymmetrically arranged and separated.

Genoholotype.—*Lonchodina typicalis* Ulrich and Bassler 1926. Rhinestreet shale, (Upper Devonian, Portage), Shaleton, New York.

Lonchodina cf. extenta Hibbard Plate 6, fig. 2

Lonchodina extenta Hibbard, 1927, Amer. Journ. Sci., 5th ser., vol. 13, p. 204, fig. 3d. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

"Bar thick, short, and bowed, bearing eight or nine acutely pointed denticles; those near the center being longest while the others, especially on the posterior half of the bar, decrease rather regularly in length toward the extremities of the bar. It is impossible to pick out the main cusp." (Hibbard's description).

Several fragments of a species of *Lonchodina* similar to the one figured on pl. 6, fig. 2, were found at Locality 1. These fragments appear to belong to *Lonchodina extenta* but could not be positively identified without more complete specimens.

Indiana University Paleontological Collection, No. 1938, upper New Albany shale, Locality 1, New Albany, Indiana.

Lonchodina nitela, new species Plate 6, figs. 3-5

Bar slender, rounded, strongly arched and slightly bowed; cusp inclined, rounded, bluntly pointed, and gently curved toward the concave side of the bar; denticles long, slender, rounded, and gently curved toward the cusp and the concave side of the bar; escutcheon small. Length, about 2.5 mm.

The species differs from *L.? projecta* Ulrich and Bassler in the stronger arching of the bar and greater number of posterior denticles.

Holotype.—Indiana University Paleontological Collection, No. 2317, lower New Albany shale, Locality 32, Prather, Indiana; Paratype No. 2325, same locality; Paratype No. 2326, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 26, 30, and 32.

Lonchodina? erecta, new species Plate 6, figs. 6, 7

Bar moderately heavy, laterally compressed, strongly arched, but not bowed. Cusp long, straight, flattened, with a suggestion of sharp edges, situated about one-third the length of the bar from one end; denticles inserted, long, slender, needle-like and gently curved toward the cusp with 10 on one side and 6 on the other. No escutcheon apparent. Height of holotype, 1.5 mm.

The species is characterized by the long straight cusp, and the slender denticles curving toward the cusp. It is somewhat similar to *L. subsymmetrica* Ulrich and Bassler, but their species has a curved cusp which is broader than the cusp *L.? erecta.*

Holotype.—Indiana University Paleontological Collection, No. 1895, middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Rare in the middle of the New Albany shale at Localities 18, 19, and 20.

Lonchodina multidens Hibbard Plate 6, fig. 8

Lonchodina multidens Hibbard, 1927, Amer. Journ. Sci., 5th ser., vol. 13, p. 203, fig. 3i, Rhinestreet shale, (Upper Devonian, Portage), Shaleton, New York.

Bar rounded, moderately heavy, strongly arched, and unsymmetrical, with one side of the bar considerably longer than the other. Cusp conical, short, and difficult to distinguish. Denticles separated, conical, and straight; usually 10 anterior and 7 posterior. One of the posterior denticles is nearly as large as the cusp, and there are 2 or 3 denticles between this large denticle and the cusp; these 3 or 4 denticles and the cusp occupy the highest part of the arched bar. Length, 1.5-2.2 mm.

The specimens from the New Albany referred to the species seem to be larger than the holotype, but agree well in general proportions.

Plesiotype.—Indiana University Paleontological Collection, No. 1890, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 27, and 28.

Lonchodina? species Plate 6, fig. 9

Bar heavy, rounded, moderately arched, and strongly bowed near the posterior end; cusp not easily distinguishable; denticles closely appressed, with some fusion, apparently inserted, short, rounded, laterally compressed with a suggestion of sharp edges, and abruptly pointed; escutcheon small; strong lateral ridge on the anterior portion of the bar.

Known from a single specimen.

Indiana University Paleontological Collection, No. 1939, lower New Albany shale, Locality 29, north of Charlestown, Indiana.

Lonchodina? projecta Ulrich and Bassler Plate 6, fig. 10, plate 11, fig. 1

Lonchodina? projecta Ulrich and Bassler 1926, Proc. U. S. Nat. Mus., vol. 68, p. 35, pl. 5, figs. 9, 10. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Bar heavy, rounded, arched upward, but not bowed inward. Cusp strongly curved and flattened; denticles large, rounded and gradually tapering. The posterior denticles slender and straight, but the anterior ones are curved toward the cusp and are broader at the base. Escutcheon present.

There are six anterior and five postreior denticles on the specimens referred to the species from the New Albany shale. Ulrich and Bassler's figures appear to the writer to be figures of broken specimens, and for this reason the New Albany specimens have been referred to this species in spite of the larger number of posterior denticles. Length, about 2 mm.

Plesiotypes.—Indiana University Paleontological Collection, No. 1893, upper New Albany shale, Locality 2, southwest of Henryville, Indiana. No. 1894, upper New Albany shale, Locality 14, southeast of Henryville.

Occurrence.—Rare in the upper and lower New Albany shale at Localities 1, 2, 3, 14, 26, 27, and 32. Doubtfully in the middle part of New Albany shale.

Lonchodina species Plate 6, fig. 11

Bar slender, rounded, strongly arched, and slightly bowed toward one end; cusp not distinguishable; denticles separated, slender, rounded, sharply pointed, and decreasing in size toward the ends of the bar; no escutcheon.

Somewhat similar to *L. irregularis* Holmes but the bar appears to be more rounded, and the denticles less inclined.

Known from a single specimen.

Indiana University Paleontological Collection, No. 2268, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Lonchodina distans, new species Plate 6, fig. 13; plate 10, fig. 3

Bar narrow, rounded, moderately arched and bowed especially near the posterior end. Cusp short, gently curved, rounded and sharply pointed. Denticles rounded, gradually tapering, and separated by their own width or less, posterior denticles nearly straight, anterior denticles more or less curved toward the cusp. Escutcheon large. Length, up to 2.2 mm.

The species is somewhat similar to *L. discreta* Ulrich and Bassler, but seem to differ in having an escutcheon and unsymmetrically arched bar.

Holotype.—Indiana University Paleontological Collection, No. 2327, upper New Albany shale, Locality 13, south of Henryville, Indiana. Paratype No. 1892, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 3, 6, 8, 9, 10, 12, 13, and 14.

Lonchodina acutula, new species Plate 6, fig. 14

Bar of medium weight, rounded, gently arched and slightly bowed. Cusp rounded, gradually tapering and situated subcentrally. Denticles similar to cusp in shape, closely spaced, separate, and decreasing in size toward both ends of the bar. No escutcheon. Length of holotype, 1.5 mm.

The species is characterized by the slightly inclined cusp and the short closely spaced denticles.

Holotype.—Indiana University Paleontological Collection, No. 1918, lower New Albany shale at Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower part of New Albany shale at Locality 26.

Lonchodina tenuis, new species Plate 6, fig. 17

Bar thin, narrow, slightly bowed and strongly arched with one side longer than the other. Cusp rounded, parallel-sided, abruptly pointed, long and slender; denticles long, slender, rounded, acutely pointed, and separated, about eight anterior and five posterior denticles present. Length about 1.5 mm.

The cusp and the group of denticles on the arch are similar in appearance to *L. irregularis* Holmes, but they are not inclined to the bar as they are in *L. irregularis*. *L. tenuis* differs from *L. multidens* Hibbard in having a thinner bar, and more widely separated denticles.

Holotype.—Indiana University Paleontological Collection, No. 1891, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 27, and 28.

Lonchodina bicornis, new species Plate 10, figs. 1, 2

Bar thin, highly arched upward and slightly bowed outward. Cusp broad at the base and gradually tapering, ovate in cross section, and relatively short. The largest denticle is separated from the cusp by one or two small denticles, and these two or three denticles with the cusp occupy the highest part of the arch. Denticles separated, similar to the cusp in shape and subequal for the most part, but between some of the larger subequal denticles a single smaller denticle may occur. Length, about 1.2 mm.

Holotype.—Indiana University Paleontological Collection, No. 1866. Paratype No. 1867, both types from the upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 2, 11, and 14.

Lonchodina torta, new species **Plate 10, fig. 4**

Bar heavy, rounded, strongly arched, laterally bowed and twisted near the cusp so that the two ends of the bar are not in the same plane. Cusp rounded, slender and gradually tapering; denticles similar to the cusp in shape, and separated. Length, about 2.8 mm.

The species is characterized by the large size of the tooth, the large rounded cusp and denticles; and the twisting of the bar. The majority of specimens are broken due to the fact that the two ends of the bar are not in the same plane.

Holotype.—Indiana University Paleontological Collection, No. 1948, upper New Albany shale, Locality 11, north of Henryville, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 10 and 11.

Lonchodina prava, new species **Plate 10, fig. 10**

Bar rounded, strongly arched, and bowed with the anterior portion twisted so that the denticles on this part of the bar are not in the same plane as those on the posterior portion. Cusp rounded, strongly bent near the base, slender and probably sharply pointed. Denticles rounded, slender, separate and sharply pointed. Length, 1.5 mm.

The species differs from *L. subsymmetrica* Ulrich and Bassler in the stronger curvature of the cusp and greater number of denticles.

Holotype.—Indiana University Paleontological Collection, No. 2297, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in middle New Albany shale at Locality 20.

Lonchodina subsymmetrica Ulrich and Bassler Plate 11, fig. 2

Lonchodina subsymmetrica Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 34, pl. 5, fig. 8; pl. 6, figs. 5, 6, 7; pl. 1, fig. 24? Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Bar heavy, rounded, and arched; posterior end laterally curved. Cusp short, large, rounded and slightly curved; denticles rounded, slender and separate; about 5 posterior and 7 anterior. Escutcheon large. Length, about 1.7 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 2280, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Genus FALCODUS, new genus

Bar broad, and laterally compressed with the anterior portion bent sharply downward immediately posterior to the cusp, anterior portion usually flattened so that the denticles are in the same plane as those on the posterior portion, but the anterior portion may be slightly curved; usually a posterior downward projection, and the posterior end of the bar is always broad and denticulated with the denticles inclined upward and backward. Cusp small, not always easily distinguished, laterally compressed, and sharply pointed. Denticles laterally compressed, with a suggestion of sharp edges, and closely appressed. Cusp and denticles apparently inserted.

Genoholotype.—*Falcodus angulus,* new species.

Falcodus angulus, new species Plate 7, fig. 9; text fig. 3, no. 3

Bar broad, laterally compressed, with the anterior portion longer than the posterior, posterior downward projection present. Cusp short, not easily distinguished, laterally compressed, and acutely pointed, situated at the point of anterior curvature. Denticles closely appressed, and similar to the cusp in shape. A median ridge extends the full length of the bar. Length of holotype, 1.4 mm.

Differs from *F. conflexus* in the relative lengths of the anterior and posterior portions of the bar.

Holotype.—Indiana University Paleontological Collection, No. 1830; Paratype 1829, both types from the upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Upper and middle New Albany shale, abundant at Localities 1 and 2; rare at Localities 5, 6, 8, and 20.

Falcodus tortus, new species Plate 7, fig. 4

Bar thin, and laterally compressed with the anterior portion of the bar laterally twisted so that the denticles near the cusp incline toward one side while those toward the end of the bar incline toward the other; no posterior downward projection present. Cusp small, short, acutely pointed, closely crowded and apparently inserted. Denticles closely appressed, apparently inserted, and unequal in length but without alternation. Length of holotype, 0.7 mm.

Holotype.—Indiana University Paleontological Collection, No. 1833, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1 and 3.

Falcodus species Plate 7, fig. 5

Bar laterally compressed, with the anterior portion curved laterally, probably a posterior downward projection present. Cusp short, broad at the base and acutely pointed; denticles closely appressed, small, subequal on the posterior portion of the bar, larger and longer on the anterior portion. Slight median ridge extends the full length of the bar. Length, 0.6 mm.

Differs from other species of *Falcodus* in the laterally curving anterior portion of the bar.

Known from a single specimen.

Indiana University Paleontological Collection, No. 2355, upper New Albany shale, Locality 14, southeast of Henryville, Indiana.

Falcodus conflexus, new species Plate 7, fig. 6

Bar laterally compressed, broad, with short posterior downward projection. Cusp flattened, broad at the base and acutely pointed; denticles numerous, closely appressed, unequal in length but without alternation. Lateral ridge as in *F. angulus.* Length of holotype, 1.2 mm.

Differs from *F. angulus* in the relative proportions of the posterior and anterior portions of the bar.

Holotype.—Indiana University Paleontological Collection, No. 1832, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Upper New Albany shale, common at Locality 6; rare at Localities 1, 3, 8, 10, and 14.

Falcodus? granulosus, new species Plate 7, fig. 10

Bar thin, flattened, and highly arched; no cusp distinguishable; denticles numerous, subequal, and apparently inserted. Strong lateral flange near the lower margin of the bar and extending nearly the whole length of the bar. Bar and denticles covered with minute granules. Length, about 1.5 mm.

Holotype.—Indiana University Paleontological Collection, No. 2254, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Localities 1, 3, 6, 8, and 14.

Genus SPATHODUS Branson and Mehl, 1933

Tooth small, short, and blade-like; bar heavy, laterally compressed, straight or slightly bent; no cusp present; denticles flattened, apparently inserted, and fused, higher at the posterior[44] end; escutcheon large, usually with smooth sides, but the bar above the escutcheon may be expanded and carry denticle-like structures, these are distinctly to one side of the knife-like crest of denticles.

The species of the genus with the bar expanded and noded above the escutcheon seem to offer a connecting link between the Prioniodinidae and the Polygnatidae.

Spathodus differs from *Priniodella* in having short, almost entirely fused denticles; from *Panderodella* and *Polygnathellus* in lacking strong lateral ridges.

Spathodus is probably a synonym of *Gnathodus* Pander, but until the true characters of Pander's genus are determined it will be advisable to use the name *Spathodus.*

Genoholotype.—*Spathodus primus* Branson and Mehl, 1933.

Spathodus strigilis, new species

Text fig. 3, Nos. 1a, 1b,; pl. 7, fig. 15; pl. 12, fig. 11

Bar heavy, short, straight, and laterally compressed. Denticles short, flattened, free at the tips only, higher at posterior end of the bar, and apparently deeply inserted. There is no depression or suture between the denticles, and the bar, therefore, has a smooth appearance. Usually a single row of denticles, but the tips of denticles above the escutcheon have a tendency to become elongate laterally and form short transverse ridges. Escutcheon situated subcentrally; bar above escutcheon sometimes thickened. Length of holotype, 1.9 mm.

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[44] The broader, high end of the bar was regarded by Branson and Mehl as the anterior. The genus appears to be closely related to **Polygnathus,** and in the latter genus the high end is posterior. In **Polygnathellus** Ulrich and Bassler regarded the high end as posterior. On a basis of this precedent it seems best to regard the higher end as posterior in **Spathodus.**

Holotype.—Indiana University Paleontological Collection, No. 1875, upper New Albany shale, Locality 10, Rockford, Indiana. Paratype No. 1878, upper New Albany shale, Locality 1, New Albany, Indiana. Paratype No. 2324, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Common in the upper New Albany shale at Locality 11; rare at Localities 1, 2, 3, 4, 5, 6, 8, 9, and 10; rare in lower New Albany shale at Localities 26, 32, and 33.

Spathodus parvus, new species Plate 7, fig. 16

Bar short, heavy, straight and laterally compressed with subcentral thin-walled escutcheon. Denticles short, somewhat rounded, distinctly separated, apparently inserted and higher at the posterior end of the bar. Length of holotype, 1 mm.

The species differs from *S. rectus* (Holmes) in having the longer denticles at the posterior end of the bar and a smaller number of denticles. It differs from *S. strigilis* in having fewer denticles and the fact that the denticles are rounded, and free throughout a greater part of their length. *S. parvus* is smaller than either *S. strigilis* or *S. rectus* (Holmes).

On some specimens similar to *S. parvus* a lateral ridge is developed on both sides of the bar at the anterior end. (See Plate 12, figure 7). This ridge is not large nor conspicuous, but suggests that *S. parvus* is merely the young stage of some species of *Polygnathus* as these ridges could with further enlargement become the plate of *Polygnathus,* and the crest become subordinated. The writer has been unable to prove or disprove this suggestion with the material at hand, and it has seemed best for the present to call *S. parvus* a species.

Holotype.—Indiana University Paleontological Collection, No. 1882, upper New Albany shale, Locality 3, north of New Albany, Indiana. Young *Polygnathus?* for comparison, No. 1883, upper New Albany shale, Locality 14, New Albany, Indiana.

Occurrence.—Common in the upper New Albany shale at Localities 1, 2, 3, and 6; rare at Localities 8, 9, 10, and 11.

Spathodus subrectus (Holmes) Plate 7, fig. 17

Panderodella subrecta Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, art. 5, p. 31, pl. 10, fig. 15. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama. Cooper, 1931, Jour. Paleo., vol. 5, p. 151, pl. 20, fig. 18. Upper Ohio shale, northeast of Columbus, Ohio.

Bar heavy, laterally compressed, and the anterior end slightly deflected. Denticles subequal, inserted, short and evenly spaced, with those on the long posterior side spear-shaped, and those on the deflected anterior side needle-like. There is a prominent escutcheon, elongate laterally, and situated near the anterior end of the bar at the point of deflection. Length, about 1.5 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1879, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Abundant in the upper New Albany shale at Localities 11 and 14; common at Locality 13; rare at Locality 9, and rare in the middle part of the New Albany shale at Locality 20.

Spathodus duplidens, new species Plate 12, figs. 1-4

Bar heavy, broad, nearly straight, short, laterally compressed and more or less thickened aborally. Denticles short, apparently inserted, closely appressed, free at the tips only; 2 or 3 larger denticles at the posterior end of the bar. Surface of the one side of bar usually smooth, but a slight depression or suture between the denticles is observable on some specimens. The species is characterized by the development of a lateral expansion on one side of the bar above the escutcheon. This lateral expansion carries two or three ridge-like denticle structures. Escutcheon subcentral, and more or less thickened. Length of holotype, 1.9 mm.

The species is distinguished from *S. strigilis* by the lateral expansion of the bar and the group of large posterior denticles.

Holotype.—Indiana University Paleontological Collection, No. 1876; Paratype No. 1877, both types from the upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Abundant in the upper New Albany shale at Locality 11; common at Locality 10; rare at Localities 1, 3, 6, 9, 12, and 13.

Spathodus rectus (Holmes) Plate 12, fig. 10

Panderodella recta Holmes in Butts, 1926, Geol. Survey Ala., special report no. 14, Geology of Alabama, p. 160, pl. 48, fig. 1. Chattanooga shale, 4 miles west New Market, Madison County, Alabama.-Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, art. 5, p. 30, pl. 10, fig. 14. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Bar nearly straight, broad and laterally compressed, with prominent escutcheon near the anterior end of the bar. Denticles short, somewhat rounded, and more nearly separated than in other species of the genus.

The species is closely related to *S. subrectus,* as pointed out by Holmes 1928, and is difficult to distinguish. The difference between the two species is one of degree and a difference hard to see unless one has specimens of both species to compare. In both species the anterior end of the bar may be deflected, but *S. subrectus* has this deflection to a greater degree, and the anterior portion of the bar is more flattened than in *S. rectus.* Another difference lies in the more rounded aspect of the denticles in *S. rectus,* and in the larger more laterally elongate escutcheon. Length, about 2 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1881, upper New Albany shale, Locality 11, north of Henryville, Indiana.

Occurrence.—Abundant in the upper New Albany shale at Localities 11 and 14; rare at Localities 1, 3, 7, and 13.

Family POLYGNATHIDAE Ulrich and Bassler, 1926

Conodonts consisting of plate and denticulated carina or blade. The plate may be developed on one or both sides of the carina and is variously marked by nodes, tubercules, ridges or pustules. Blade, when present, denticulate, and when the blade is absent the posterior portion of the carina has closely appressed, fused, and apparently inserted denticles. Escutcheon usually present.

POLYGNATHELLUS Ulrich and Bassler, 1926

Tooth consisting of a curved crest made up of short, apparently inserted, and closely appressed denticles. On the convex side of the crest there is a narrow smooth basal flange, and on the concave side there is a wider, tuberculated flange extending the full length of the crest. Cusp usually not distinguishable.

The essential character of the genus is the tuberculated flange extending the entire length of the crest.

Genoholotype.—*Polygnathellus typicalis* Ulrich and Bassler, 1926. Rhinestreet shale (Upper Devonian, Portage), Shaleton, New York.

Polygnathellus similis, new species Plate 7, fig. 20, 21

Crest short, and slightly bowed outward. Denticles short, narrow, closely appressed, and decreasing in size from the middle of the crest toward the posterior end. Convex side has a small narrow flange; concave side has a broad flange which extends the full length of the crest and is covered with tubercles on the posterior half and is smooth on the anterior half. Length of holotype, 1.5 mm.

Somewhat similar to *P. typicalis* Ulrich and Bassler but differs in the greater number of denticles and smaller tuberculated area on the concave flange.

Holotype.—Indiana University Paleontological Collection, No. 1901, upper New Albany shale, Locality 1, New Albany, Indiana. Paratype No. 1945, upper New Albany shale, Locality 14, southeast of Henryville, Indiana.

Occurrence.—Rare in the upper part of the New Albany shale at Localities 1, 2, and 14.

Genus GONDOLELLA Stauffer and Plummer, 1932

Gondolella Stauffer and Plummer, 1932, Univ. Texas Bull. 3201, pp. 41-42. Stauffer and Plummer's description:

"Tooth tongue-, canoe-, or gondola-shaped with posterior end pointed; bar or base slender to thick and broad, usually keeled on the under side; upper surface flat or concave and usually covered by transverse ridges broken along the median line by a series of short, often stout, denticles, which may become more prominent and more closely set near the posterior end. The denticles may be more or less fused to form a ridge or carina. The anterior end is marked by a prominent denticle or forward-projecting cusp, which in some species is double pointed. Under side is smooth except for the keel which usually has a median furrow bounded on each side by slightly elevated ridges. These make a flaring loop anteriorly but converge and on some specimens disappear posteriorly. At the looped end the furrow or groove expands into a cavity bounded by the loop."

Genoholotype.—*Gondolella elegantula* Stauffer and Plummer, 1932.

Gondolella? nodosa, new species Plate 8, figs. 24, 25

Tooth small, consisting of a narrow base, a median carina, and a single row of nodes on each side of the carina. Carina with nodes and denticles more or less fused especially near the posterior end, and flanked by deep grooves; lateral nodes originate near the base of the tooth and rise as high as the carina, but posteriorly one or two denticles of the median carina extend behind the last lateral nodes. Aboral surface marked by a large, thin walled escutcheon situated at the posterior end, which expands wider than any other portion of the tooth and continues forward to the anterior end as a thin walled trough. Length of holotype, 0.7 mm.

The species is referred doubtfully to *Gondolella* because of the lack of prominence of the median crest.

Holotype.—Indiana University Paleontological Collection, No. 1940, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 27, 28, and 33.

Genus POLYGNATHUS[45] Hinde, 1879

Conodonts with a sublanceolate plate, blade, and carina

Polygnathus Hinde, 1879, Quart. Jour. Geol. Soc. London, vol. 35, pp. 361-362.-Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, p. 22, 23-24.-Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, pp. 43-44.-Roundy, 1926. Prof. Paper U. S. Geol. Survey, 146, p. 13.-Branson and Mehl, 1933, Univ. of Missouri Studies, vol. 8, pp. 144-145, and 146, paragraphs 2 and 3.

[45] Gnathus from Green gnathos is feminine and should retain its feminine gender when transliterated into Latin, for which determination I am indebted to Professor E. S. Stout, head of the Latin Department, Indiana University. The feminine gender of **Polygnathus** was first pointed out by Branson and Mehl, 1932.

or a row of nodes extending almost or quite the full length of the plate and dividing the plate into two subequal parts. Blade with apparently inserted denticles, highest near the posterior end, decreasing in height toward the plate and merging with the carina. Oral surface of the plate variously marked by nodes, tubercles, or ridges; aboral surface characterized by a median keel, escutcheon, and concentric lines.

Genotype.—*Polygnathus pennata* Hinde, 1879. Designated by Roundy, 1926; synonym *Polygnathus dubia* Hinde. Type figure of the genus, Hinde, 1879, pl. 16, fig. 17 selected by Roundy, 1926, as type figure of the genus and of the species *Polygnathus dubia.* Name for the specimen figured by Hinde, 1879, pl. 16, fig. 17, selected by Bryant, 1921, *Polygnathus pennata*[46]

Hinde's specimen from the Upper Devonian, (probably Portage, according to Bryant), North Evans, New York.

Polygnathus lacinata, new species Plate 8, figs. 1-3

Plate elongate and narrow, with median ridge dividing the plate into subequal parts, noded, extending the full length of the plate, with a sharp depression on each side. The carina with apparently inserted denticles is produced behind the plate. Oral edges of the plate raised and marked by elongate nodes. Aboral surface marked by median keel, large subcentral escutcheon, and concentric lines. Length, about 1.2 mm.

The species is characterized by the very narrow plate, strong carina, and single row of elongate nodes. It differs from *P. pennata* Hinde in having more regular nodes, and a larger escutcheon.

Holotype.—Indiana University Paleontological Collection, No. 2271, Paratype No. 1908, upper New Albany shale, Locality 1, New Albany, Indiana. Paratype No. 1907, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.—Common in the upper New Albany shale at Localities 2 and 8; rare at Localities 1, 3, 6, and 14.

Polygnathus linguiformis Hinde Plate 8, figs. 4, 5

Polygnathus linguiformis Hinde, 1879, Quart. Jour. Geol. Soc. London, vol. 35, p. 367, pl .17, fig. 15. Genesee (Upper Devonian), North

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[46] International Rules of Zoological Nomenclature, Art. 28.

Evans, New York. North shore of Lake Erie, erratic ''Genesee boulders.''

Polygnathus simplex Hinde, 1879, Quart. Jour. Geol. Soc. London, vol. 35, p. 367, pl. 17, fig. 18. Genesee (Upper Devonian), North Evans, New York.

Polygnathus linguiformis Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 8, p. 25, pl. 11, figs. 1-9, pl. 14, fig. 2. Genundewah (Upper Devonian), North Evans, New York.-Branson and Mehl, 1933, University of Missouri Studies, vol. 8, pp. 148 and 150, pl. 12, figs. 6, 7. New figures of Hinde's specimens.

Plate elongate, and highly arched longitudinally with the anterior portion extending downward as a "tongue-like process," marked on the oral surface by transverse ridges. The carina extends as a noded ridge from the central portion of the plate and rises to a denticulated carina behind the plate. No median ridge on the anterior "tongue-like process". There is a depression on each side of the median ridge. Plate on one side is flat and narrow; on the other side it is wide but rises so abruptly that it stands nearly vertically. Both sides of posterior portion of the oral surface marked by short transverse ridges. Aboral surface characterized by median keel, concentric lines and a small escutcheon. Length, about 2 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1786, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Common in the lower New Albany shale at Locality 26; rare at Localities 27, 28, 32, and 33.

Polygnathus pennata Hinde Plate 8, figs. 6, 7

Polygnathus pennatus Hinde, 1879, Quart. Jour. Geol. Soc. London, vol. 35, p. 366, pl. 17, fig. 8. Upper Devonian, North Evans, New York.

Polygnathus dubius Hinde (in part), 1879. Quart. Jour. Geol. Soc. London, vol. 35, pp. 362-364, pl. 16, fig. 17. Upper Devonian, North Evans, New York.

Polygnathus pennatus Clark, 1867, Sixth Ann. Rept. State Geologist New York, pl. A 1, fig. 9.-Grabau, 1899, Bull. Buffalo Soc. Nat. Sci., vol. 6, p. 156, fig. 39.-Grabau and Shimer, 1910, North American Index Fossils, vol. 2, p. 244, fig. 1536 a.-Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, pp. 23-24, pl. 10, figs. 1-9, Upper Devonian, Genundewah Eighteen Mile Creek New York.-Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus. vol. 68, fig. 5, numbers 6, 7.

Polygnathus dubius Roundy, 1926, Prof. Paper U. S. Geol. Survey, 146, p. 13, pl. 3, fig. 9.

Polygnathus pennatus Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 18, pl. 7, figs. 10, 11, 12.

Polygnathus pennata Branson and Mehl, 1933, Univ. of Missouri Studies, vol. 8, pp. 144-145, and 146, paragraphs 2 and 3, pl. 11, fig. 3.

Not *Polygnathus dubia* Branson and Mehl, 1933, Univ. of Missouri Studies, vol. 8, pp. 146-147, pl. 11, fig. 5. (This species needs a new name).

Plate narrow and arched upward, longitudinally, with furrows on each side of the carina; carina low and crowned with tubercles, 8 to 16 in number; merging posteriorly with the blade which rises abruptly behind the plate and carries about 6 denticles. Oral surface marked by coarse, somewhat tuberculated ridges arranged at right angles to the carina; aboral surface characterized by strong keel, small escutcheon and concentric lines. Length, about 1.2 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 2353, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 26 and 32; rare at Localities 30 and 33.

Polygnathus peracuta Bryant Plate 8, fig. 8

Polygnathus peracutus Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, p. 25, pl. 10, fig. 12. Genundewah (Upper Devonian), North Evans, New York.

Plate elongate, subtriangular in outline and slightly arched longitudinally. Carina extending the full length of the plate as a row of nodes, but without median depressions or furrows on each side of the row of nodes. Oral surface marked by numerous somewhat irregularly arranged nodes or tubercles, but the nodes have a tendency to arrange themselves in rows parallel to the median ridge. Aboral surface marked by concentric lines and median keel; no escutcheon observed, but probably present. Length, about 1.3 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1909, upper New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 27 and 28; rare at Localities 26 and 30.

Polygnathus bryanti, new species Plate 8, figs. 9, 10

Polygnathus tuberculatus Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, pp. 25-26, pl. ,12, figs. 7-9, Genundewah (Upper Devonian) Eighteen Mile Creek, New York.

Plate massive, broad, slightly arched longitudinally, and the anterior end deflected laterally (to the left in the specimens figured by Bryant and all specimens from the New Albany collected to date; later collections may show rights). Carina laterally curved, consisting of low, more or less coalescing tubercules, and merging posteriorly with a short blade. Oral surface marked by tubercles which tend to coalesce and form ridges radiating from the posterior portion of the plate; aboral surface characterized by a sharp keel, small escutcheon and concentric lines. Length, about 1.5 mm.

The species differs from *P. tuberculata* Hinde in the lateral deflection of the anterior portion of the plate and carina.

Holotype.—Indiana University Paleontological Collection, No. 2359, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26 and 32.

Polygnathus signata, new species Plate 8, fig. 11

Plate narrowly lanceolate, arched longitudinally and slightly flexed laterally. Carina represented on the plate by a median row of nodes. Oral surface covered with nodes tending to be arranged in rows parallel to median ridge and becoming smaller toward the edge of the plate. Near the point of junction of the plate the lateral row of nodes on each side of median ridge rise to form small cristulae. Aboral surface marked by concentric lines, and median keel with central furrow and an escutcheon situated near the posterior end of the plate. Length, about 1.2 mm.

This species si similar to *P. foliata* Bryant in the development of lateral cristulae, but differs in not having the edges of the plate curled and by having a marked median depression. Differs from *P. peracuta* Bryant in not having triangular shape and having lateral cristulae.

Holotype.—Indiana University Paleontological Collection, No. 1800, lower New Albany shale, Locality 30, Prather, Indiana.

Occurrence.—Common in lower New Albany, at Localities 26 and 30.

Polygnathus rugosa, new species Plate 8, figs. 12, 13

Plate massive, elongate and slightly arched longitudinally. Carina extending the length of the plate as a distinct ridge of tubercles. Oral surface marked by strong transverse ridges perpendicular to median ridge. Aboral surface characterized by concentric lines, median keel, and small escutcheon. Length of holotype, 1.5 mm.

Holotype.—Indiana University Paleontological Collection, No. 1916, lower New Albany shale, Locality 30, Prather, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 30 and 32.

Polygnathus foliata Bryant Plate 8, figs. 14-17

Polygnathus foliatus Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, p. 24, pl. 10, figs. 13-16. Genundewah, (Upper Devonian) Eighteen Mile Creek, New York.

Plate small, arched longitudinally, usually narrow and elongate but may be expanded on one side. Carina extending the full length of the plate as a row of nodes with a shallow furrow on each side of the row of nodes. Oral margins of the plate more or less raised and covered with small nodes. Aboral surface characterized by median keel, concentric lines, and small escutcheon. Length, about 0.8 mm.

Plesiotypes.—Indiana University Paleontological Collection, Nos. 2360, 2361, lower New Albany shale, Locality 30, near Prather, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 26, 27, and 28; rare at Localities 30 and 33.

Polygnathus rhomboidea Ulrich and Bassler? Plate 8, fig. 18

Polygnathus rhomboideus Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 46, pl. 7, fig. 6. Hardin sandstone, Mt. Pleasant, Tenn.-Holmes, 1928, Proc. U. S. Nat. Mus. vol. 72, p. 32, pl. 11, figs. 11, 12. Chattanooga shale 13 miles north-northeast of Huntsville, Alabama.

Plate massive and subromboidal in shape, with the carina extending the length of the plate as a low tuberculated ridge. Blade short and narrow, with several denticles varying in size and shape. Oral surface marked by tubercules arranged concentricly on the anterior portion. Aboral surface unknown. Length, about 1.5 mm.

The specimen figured from the New Albany shale differs from the specimens figured by Ulrich and Bassler, and by Holmes, in that the carina is lost at the middle of the plate and the anterior concentric rows of nodes are much stronger.

Figured specimen.—Indiana University Paleontological Collection, No. 1942, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Polygnathus alata, new species Plate 8, figs. 19, 20

Plate small, narrow, and arched longitudinally; carina a high ridge tuberculated on the anterior portion only, with a deep furrow on each side. Oral margins of the plate sharply upturned and forming cristulae at the posterior end, oral surface usually smooth but there may be faint indications of nodes on the margin; aboral surface marked by a sharp keel, and small escutcheon. Length, about 0.7 mm.

Holotype.—Indiana University Paleontological Collection, No. 1913, lower New Albany shale, Locality 30, near Prather, Indiana.

Occcurrence.—Rare in the lower New Albany shale at Localities 26, and 33.

Polygnathus rimulata, Ulrich and Bassler Plate 8, fig. 21

Polygnathus rimulatus Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 45, pl. 1, figs. 8, 9. Rhinestreet shale, (Upper Devonian, Portage), Shaleton, New York.

Plate narrow, long, strongly arched longitudinally, and slightly flexed laterally near the anterior end. Carina consisting of a moderately high tuberculated ridge flanked by deep furrows. Oral margins of the plate high, and marked by short, sharp, regular ridges; at the posterior end of the plate the median furrows are deeper and the edges of the plate form cristulae. Aboral surface marked by a sharp keel, concentric lines and a rounded escutcheon. Length, about 0.8 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 2362, lower New Albany shale, Locality 30, near Prather, Indiana.

Occurrence.—Common in the lower New Albany shale at Localities 26, 30, 32, and 33.

Polygnathus sulcata, new species Plate 8, figs. 22, 23

Plate small, massive, arched longitudinally and flexed near the anterior end. Carina a sharp turberculated ridge flexed anteriorly and with shallow furrows on each side which become deeper toward the posterior end of the plate. Oral surface marked by sharp ridges pinnately arranged. Aboral surface characterized by a broad keel and large escutcheon, but without concentric lines. Length, about 1.5 mm.

Holotype.—Indiana University Paleontological Collection, No. 1944, upper New Albany shale, Locality 9, north of Rockford, Indiana.

Occurrence.—Rare in the upper New Albany shale at Locality 9.

Polygnathus newalbanyensis, new species Plate 8, figs. 26-28

Plate leaf-like and divided into unequal parts by a distinct, noded median ridge that extends the full length of the plate; blade short, with about 10 denticles, largest near the middle. The oral surface of the broadest side of the plate is more or less inclined upward and marked by sharp transverse ridges, while the narrow side is flat and covered with small tubercles. At the posterior end of the plate three lateral cristulae flank the main carina, with two on the tuberculated side of the plate and one on the ridged side. Aboral surface characterized by median keel, concentric lines and small elongate escutcheon. Length, 2-3.2 mm.

The species is easily recognized by the two types of oral markings.

Holotype.—Indiana University Paleontological Collection, No. 2269; Paratypes Nos. 1911, 1912, upper New Albany shale, Locality 3, north of New Albany, Indiana.

Occurrence.—Abundant in the upper New Albany shale at Localities 1, 2, 3, 6, 8, 10, and 14; common at Locality 9; rare at Localities 4, 5 and 12.

Polygnathus caelata Bryant Plate 8, figs. 29-32

Polygnathus caelatus Bryant, 1921, Bull. Buffalo Soc. Nat. Sci., vol. 13, p. 25, pl. 13, figs. 1-13. Genundewah (Upper Devonian), North Evans, New York.

Plate large, massive, strongly arched longitudinally and subovate, with a strong, high, irregular carina extending the full length of the plate and flanked by shallow furrows. Blade short, with about 6 apparently inserted denticles. Oral surface marked by irregular nodes or ridges arranged at about right angles to the median carina. Aboral surface marked by median keel, concentric lines, and small subcentral escutcheon. Length, about 2 mm.

The species is characterized by its large size, and coarse markings on the oral surface. Bryant allowed for considerable variation in the species and the specimens from the New Albany are well within his limits of variation.

Plesiotypes.—Indiana University Paleontological Collection, No. 1797, lower New Albany shale, Locality 30, near Prather, Indiana; No. 1946, lower New Albany shale, Locality 28, Chelsa, Indiana; No. 2354, lower New Albany shale, Locality 27, Chelsa, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 27, 28, 30, and 33.

Polygnathus scapha, new species Plate 8, figs. 33-35; text fig. 3, nos. 2a-c

Plate narrow, and elongate with the carina a noded ridge flanked by deep furrows. Blade short with 4 or 6 denticles. Oral surface marked by a single row of nodes along the margin of the plate. Aboral surface characterized by small escutcheon, concentric lines and median keel. Length of holotype, 2 mm. The species is characterized by the single row of large nodes that outline the plate.

Holotype.—Indiana University Paleontological Collection, No. 1910, upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Common in the upper New Albany shale at Locality 6; rare at Localities 2, 3, 5, 8, 10, and 14.

Polygnathus rotundiloba Bryant Plate 8, figs. 36, 37

Polygnathus rotundilobus Bryant, 1921. Bull. Buffalo Soc. Nat. Sci., vol. 13, pp. 26, 27, pl. 12, figs. 1-6. Genundewah, (Upper Devonian), North Evans, New York.

Plate massive, short, and subtriangular with the anterior end pointed and projecting downward. Blade extending behind the plate for a distance nearly equal to the length of the plate, and the carina represented by a row of large nodes. Oral surface marked by large tubercles irregularly arranged. Aboral surface characterized by concentric lines, small subcentral escutcheon and strong median keel. Length, about 2 mm.

Plesiotypes.—Indiana University Paleontological Collection, No. 2284, lower New Albany shale, Locality 30, near Prather, Indiana. No. 2363, lower New Albany shale, Locality 32, Prather, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 30, and 32.

Polygnathus ectypa, new species Plate 8, fig. 38

Plate subovate and rather thin with the carina represented by a straight row of separate tubercles; no median furrows, but small concavities at the posterior end of the plate next the blade; blade short, with about 7 apparently inserted denticles. Oral surface marked by strong, closely spaced tubercles arranged more or less pinnately. Aboral surface unknown. Length of holotype, 1.6 mm.

The species differs from *P. rotundiloba* Bryant in its more ovate outline, more numerous turbercles and thinner plate.

Holotype.—Indiana University Paleontological Collection, No. 1799, lower New Albany shale, Locality 26 north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 26, 30, and 32.

Polygnathus plana, new species Plate 8, figs. 39-43

Plate subovate, thick and arched longitudinally. Carina extends the length of the plate as a smooth or slightly noded ridge; blade short, with the denticles apparently not inserted. Oral margins of the plate raised, and the oral surface is marked by low ridges pinnately arranged. Aboral surface characterized by a low median keel, small escutcheon, concentric lines, flat centrally but margins thick and inclined upward. Length of holotype, 2.3 mm.

The species is characterized by the rounded anterior end of the plate, the transverse, low ridges, and thick, inclined aboral margins.

Holotype.—Indiana University Paleontological Collection, No. 1903. Paratype No. 1904, both types from the upper New Albany shale, Locality 10, Rockford, Indiana.

Occurrence.—Common in the upper New Albany shale at Locality 10.

Polygnathus similis, new species Plate 8, fig. 44

Plate small, massive, narrow anteriorly and widening toward the posterior end. Carina extending nearly the full length of the plate as a slightly tuberculated ridge with the tubercles becoming more distinct near the anterior end. No median furrows, but distinct concavities near the posterior end of the plate next to the blade. Blade long, with numerous, apparently inserted denticles. Oral surface marked by a few rows of nodes running parallel to the carina. Aboral surface unknown. Length of holotype, 1.5 mm.

The species differs from *P. rhomboidea* Ulrich and Bassler in that the rows of nodes are always parallel to the carina and not arranged concentricly on the anterior portion of the plate.

Holotype.—Indiana University Paleontological Collection, No. 2285, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Polygnathus aspera, new species Plate 8, figs. 45, 46

Plate large, broad, massive, and more or less flexed; carina an irregular ridge, more or less tuberulated; blade unknown. Oral surface marked by low irregular ridges arranged more or less pinnately; posterior portion raised as high as the carina on one side, but distinctly lower on the other. Aboral surface characterized by small keel, concentric lines and a small escutcheon. Length, about 2.5 mm.

The species differs from *P. caelata* Bryant in being broader, flatter, and in having a lower carina.

Holotype.—Indiana University Paleontological Collection, No. 1905, lower New Albany shale, Locality 26, north of Speed, Indiana.

Occurrence.—Rare in the lower New Albany shale, at Locality 26.

Polygnathus species Plate 9, figs. 11, 12

Plate broad, ovate, and relatively thin, with the carina extending the length of the plate as a row of nodes; blade unknown. Oral surface marked by small tubercles on the anterior and posterior thirds of the plate, and in the middle third by low sharp ridges arranged pinnately with the carina. Aboral surface with thin sharp keel, concentric lines and small escutcheon.

Known from a single specimen.

Indiana University Paleontological Collection No. 2250, lower New Albany shale, Locality 26, north of Speed, Indiana.

Polygnathus species Plate 9, figs. 13, 14

Plate subovate and slightly arched, with the carina represented by a row of small nodes which becomes indistinguishable toward the anterior portion of the plate; blade short, and low with about eight apparently inserted denticles. Oral surface covered with small nodes; aboral surface concave centrally, with sharp median keel, but without concentric lines or escutcheon.

The species appears to be new, but is not named because it is known from a single broken specimen.

Indiana University Paleontological Collection, No. 1949, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Polygnathus concentrica, Ulrich and Bassler Plate 9, fig. 19

Polygnathus concentricus Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 47, pl. 8, figs. 6, 7. Hardin sandstone, Mt. Pleasant, Tennessee.—Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 32, pl. 11, figs. 5-7. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Plate broad and undulating, with the median carina extending the length of the plate, high, distinct and tuberculate near the center of the plate, and becoming faint toward both ends of the plate. Blade short, and thick with several denticles. Oral surface marked by concentrically arranged, elongate tubercles. Aboral surface with sharp keel, and concentric lines, but without escutcheon. Length, about 3 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1943, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Locality 20.

Polygnathus gyratilineata Holmes Plate 9, fig. 20

Polygnathus gyratilineatus Holmes in Butts, 1926, Geol. Surv. Ala., Spec. rpt. 14, p. 160, pl. 48, fig. 15.—Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 31, pl. 11, figs. 1, 2. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Plate subovate with the oral surface highly convex both longitudinally and transversely. Median ridge arising near the center of the plate and continuing behind the plate as a denticulated blade. Oral surface marked by sharp, concentric ridges which tend to break up into irregular, elongate tubercles away from the high central portion of the plate. Aboral surface not observed. Length, about 3 mm.

Plesiotype.—Indiana University Paleontological Collection, No. 1802, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 18, and 20.

Genus PALMATOLEPIS Ulrich and Bassler, 1926

Plate irregularly palmate and relatively thin; carina more or less curved, and denticulate in the posterior portion with the denticles fused, and apparently inserted. The denticulated portion of the carina terminates at a large conical node, situated in the anterior half of the plate; anterior to this conical node the carina continues to the anterior end of the plate as a low noded ridge or row of nodes. Carina sometimes bifurcates with a lateral carina extending to the tip of a lateral lobe. Blade and escutechon absent.

Genoholotype.—*Palmatolepis perlobata* Ulrich and Bassler, 1926. Hardin sandstone, Mt. Pleasant, Tennessee.

Palmatolepis pustulosa, new species Plate 9, figs. 1, 2

Plate thin, and rounded anteriorly, with one short, rounded lateral lobe. Carina slightly curved, decreasing in size toward the anterior end of the plate, but not dividing and extending on the lateral lobe. Oral surface covered with numerous minute pustules. Aboral surface characterized by a strong median furrow, and on the posterior portion shallow grooves traverse the plate obliquely. Length, 1-1.5 mm.

The species is characterized by the rounded anterior end, short lateral lobe and the oblique grooves on the posterior portion of the aboral surface.

Holotype.—Indiana University Paleontological Collection, No. 2364, Paratype No. 2365, both types from the middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Common in the middle New Albany shale at Locality 18.

Palmatolepis species Plate 9, fig. 3

The specimen figured appears to represent a fragment of *P. puncata* (Hinde) or some new species, but until more complete specimens are found no description can be made.

Figured specimen.—Indiana University Paleontological Collection, No. 1801, lower New Albany shale, Locality 30, near Prather, Indiana.

Occurrence.—Rare in the lower New Albany shale at Localities 30 and 33.

Palmatolepis cymbula, new species Plate 9, figs. 4, 5

Plate relatively thin, and subovate, with small, rounded lobes. Carina slightly curved, low and indistinct at the anterior margin and rising to a thin denticulated crest; not bifurcated. Oral surface marked by numerous fine pustules. Aboral surface characterized by a thin, low sharp keel and concentric lines; no escutcheon. Length, 1.5-1.8 mm.

The species differs from *P. elongata* Holmes in having a broader, more lobate outline.

Holotype.—Indiana University Paleontological Collection, No. 2367; Paratype No. 2366, both from the middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 18 and 20.

Palmatolepis pectenifera, new species Plate 9, figs. 6, 7

Plate rather thin, elongate, and sigmoidal with the carina extending the full length of the plate, strongly curved laterally, but not bifurcating. Oral surface of the plate covered with minute pustules. Aboral surface concave, and marked by concentric lines and median keel. No escutcheon. Length of holotype, 2.2 mm.

P. pectenifera is larger than *P. elongata* and is easily recognized by its sigmoidal outline, and lack of lobation.

Holotype.—Indiana University Paleontological Collection, No. 1781, middle New Albany shale, Locality 19, southeast of Henryville, Indiana.

Occurrence.—Abundant in the middle part of the New Albany shale at Localities 18, 19, and 20; common at Locality 21; rare at Locality 16.

Palmatolepis elongata Holmes Plate 9, figs. 8-10

Palmatolepis elongata Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 33, pl. 11, fig. 13. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

The plate small, narrow and elongate with the carina extending the full length of the plate, slightly curved, and not bifurcated. The oral surface of the plate is minutely pustulose. The lateral lobe on one side of the plate is considerably higher than the rest of the plate. Aboral surface with thin, medium keel and concentric lines; no escutcheon. Length, about 1.3 mm.

Plesiotypes.—Indiana University Paleontological Collection, No. 1782, middle New Albany shale, Locality 23, south of New Albany, Indiana; Nos. 2282, 2283, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Common in the New Albany shale at Locality 23; rare at Locality 20.

Palmatolepis? inequalis, Holmes Plate 9, figs. 15-18

Palmatolepis inequalis Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 33, pl. 11, figs. 8-10. Chattanooga shale, 13 miles north-northeast of Huntsville, Alabama.

Plate massive and unequally bifurcated anteriorly with the lateral lobe extending beyond the end of the plate. Carina a sharp ridge composed of fused nodes, and bifurcating subcentrally with the higher main carina extending to the anterior end of the plate and a lower secondary carina extending to the tip of the long lateral lobe. Blade short, heavy and denticulate. Oral surface covered with short tubercules arranged more or less in rows perpendicular to the carina. Aboral surface with fine concentric lines, sharp bifurcating keel, and small escutcheon. Length, about 1.8 mm.

The species differs from *P. bifurcata* Ulrich and Bassler in having a longer lateral lobe. The two species *P. bifurcata* Ulrich and Bassler, and *P. inequalis* Holmes differ from other species included in the genus in having a heavier plate, coarser oral markings, escutcheon, and blade. For these reasons reference of *inequalis* to the genus *Palmatolepis* is questioned.

Plesiotype.—Indiana University Paleontological Collectiton, Nos. 2344, 2345, 2346, 2347, middle New Albany shale, Locality 20, north of New Albany, Indiana.

Occurrence.—Rare in the middle New Albany shale at Localities 18, 19, and 20.

Palmatolepis perlobata Ulrich and Bassler Plate 9, figs. 21-23

Palmatolepis perlobata Ulrich and Bassler, 1926, Proc. U. S. Nat. Mus., vol. 68, p. 49, pl. 7, figs. 19-23. Hardin sandstone, Mount Pleasant, Tennessee.—Holmes, 1928, Proc. U. S. Nat. Mus., vol. 72, p. 34, pl. 11, figs. 16-19. Chattanooga shale, 13 miles north-northeast Huntsville, Alabama.—Bassler, 1932, Tenn. Div. Geology, Bull. 38, p. 235, pl. 26, fig. 18. (Ulrich and Bassler's figure reprinted).

Plate elongate, irregularly lobate and flexed to the right or left in the posterior portion. From the posterior end of the plate the carina curves gently to a point near the center where it abruptly turns, rises to a node, and bifurcates, sending a low noded ridge to the anterior and lateral pointed lobes. Oral surface of the plate is covered with tubercles. Denticles in the carina short, inserted, and free only at the tips. Aboral surface characterized by median keel and concentric lines. No escutcheon present. Length, up to 3.5 mm.

Plesiotype.—Indiana University Paleontological Collection, Nos. 1783, 1785, middle New Albany shale, Locality 20, north of New Albany, Indiana. No. 2256, middle New Albany shale, Locality 18, southeast of Henryville, Indiana.

Occurrence.—Abundant in the middle New Albany shale at Locality 20, common at Localities 18 and 21; rare at Localities 16, 17, and 22.

Palmatolepis minuta, new species Plate 9, fig. 24

Plate thin, and elongate with the anterior end pointed, and a sharply pointed lateral lobe. Carina bifurcating and extending to the anterior end of the plate and to the tip of the pointed laeral lobe. Oral surface covered with minute pustutles. Aboral surface not observed. Length of holotype, 1.1 mm.

The species differs from *P. perlobata* Ulrich and Bassler in the smaller size, shorter lateral lobe, and finer oral markings; from *P. pustulosa* in having the anterior end of the plate and the lateral lobe sharply pointed.

Holotype.—Indiana University Paleontological Collection, No. 1784, upper New Albany shale, Locality 1, New Albany, Indiana.

Occurrence.—Rare in the upper New Albany shale at Locality 1.

CLASS PISCES

SUBCLASS SELACHII

ORDER PLEUROPTERYGII

GENUS CLADODUS

Cladodus springeri, St. John and Worthen Plate 9, fig. 25

Cladodus springeri, St. John and Worthen, 1875, Geol. Surv. of Illinois, vol. 6, pp. 259-261, pl. 2, figs. 1-13. Lower fish-bed, Kinderhook fmn., Burlington, Iowa.

For this determination I am indebted to Mr. W. L. Bryant, Director of the Park Museum, Roger Williams Park, Providence, R. I., and the following is quoted from his letter to me:

"The tooth appears to me to be that of *Cladodus springeri* St. J. & W. This species was described in Volume 6 of the Geological Survey of Illinois, and is typically from the Kinderhook.

"Along with these occur forms described by St. J. and W. as *C. wachsmuthi, C. succinctus,* and *C. alternatus.* All of these are now thought to be variations of *C. springeri,* and while your tooth is somewhat larger and has a narrow base in a postero-antero direction, I believe it must pertain to the same fish — if not to a very close relative."

Plesiotype.—Indiana University Paleontological Collection, No. 2368, upper New Albany shale, Locality 2, southwest of Henryville, Indiana.

Occurrence.—Figured specimen only one found.

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GLOSSARY OF TERMS USED IN DESCRIPTIONS

Aboral.—Under surface or surface of attachment.

Anterior.—End of the bar near which the cusp is situated in the Prioniodidae; end of the bar toward which the denticles and cusp incline in most of the Prioniodinidae; end of the plate opposite the blade or denticulated portion of the carina in most of the Polygnathidae; low end of the bar or carina in *Spathodus, Panderodella, Polygnathellus.* In some genera, such as *Hibbardella,* anterior can not be recognized.

Anterior deflection.—Bent downward and sometimes laterally bowed anterior portion of the bar.

Appressed.—Denticles closely crowded.

Anticusp.—Spur extending downward at the anterior end of the bar below the cusp.

Arched.—Bar or plate curved upward.

Bar.—Elongate horizontal portion of the tooth carrying the denticles.

Blade.—Denticulated bar-like structure extending behind the plate in some of the Polygnathidae.

Bowed.—Bent or curved laterally.

Carina.—Vertical, denticulated ridge or row of nodes extending lengthwise across part or all of the plate in the Polygnathidae.

Crest.—Similar to the carina but higher and more predominate.

Cristula.—Small secondary carina developed at the posterior end of the plate, at one side and parallel to the main carina.

Cusp.—Large, spine-like structure.

Denticle.—Spine-like structure on the oral surface.

Escutcheon.—Diamond shaped basal expansion, pit, or cavity seen on the aboral surface.

Flange.—Large lateral ridge.

Flexed.—Curved laterally.

Height.—See length.

Keel.—Ridge extending lengthwise of the plate on the aboral surface.

Length.—Greatest dimension, including cusp or anticusp; except in some species of *Hibbardella* and *Lonchodina* where height is used for greatest dimension.

Oral.—Upper, denticulated, or ornamented surface of the bar or plate.

Pinnate.—Nodes or turbercules arranged feather-like to the carina in the Polygnathidae.

Plate.—Wide, flat or massive portion of the tooth on one or both sides of the carina in the Polygnathidae.

Posterior downward projection.—Spur projecting downward at the posterior end of the bar.

Tooth.—Entire specimen.

EXPLANATION OF PLATES

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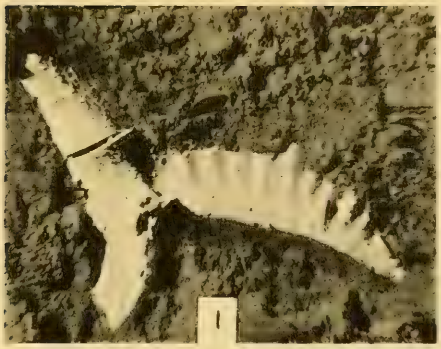
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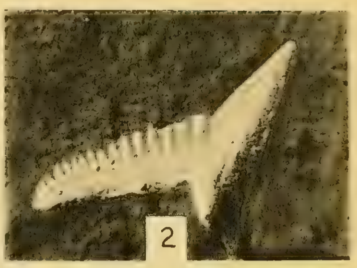
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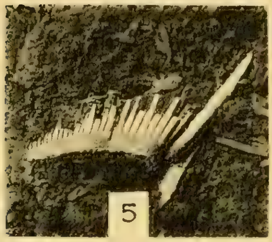
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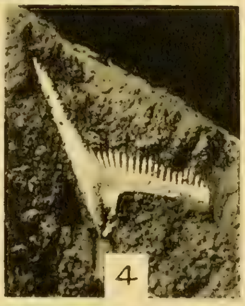
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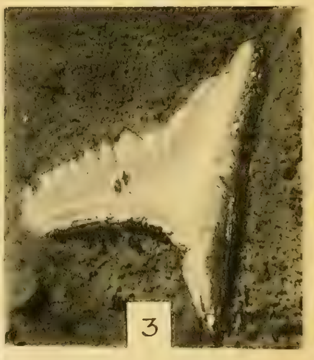
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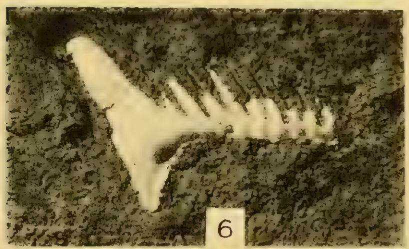
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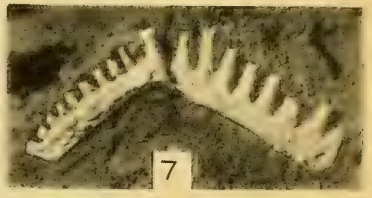
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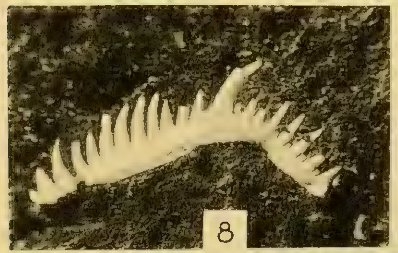
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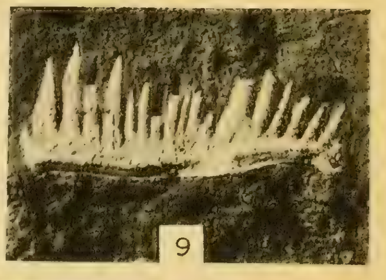
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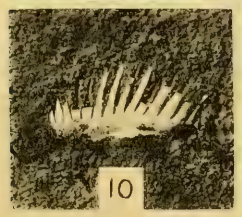
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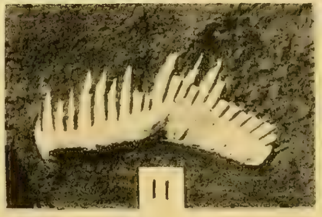
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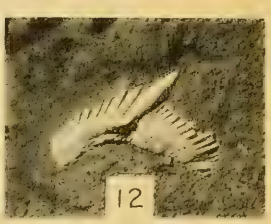
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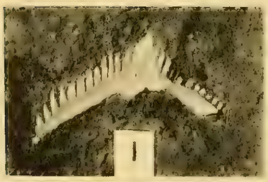
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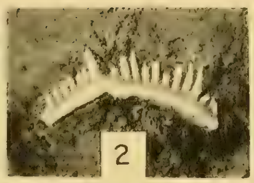
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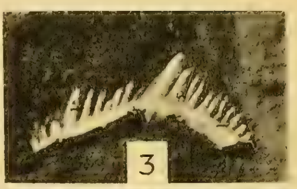
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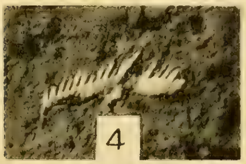
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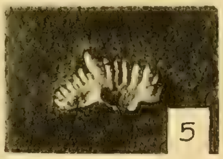
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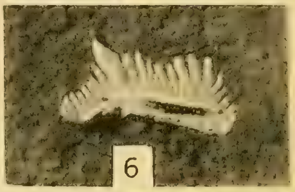
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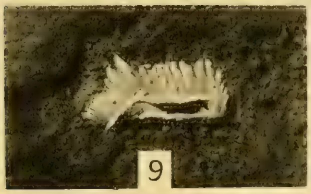
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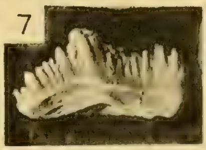
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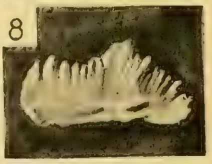
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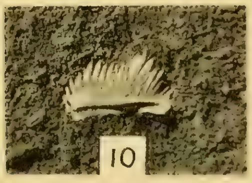
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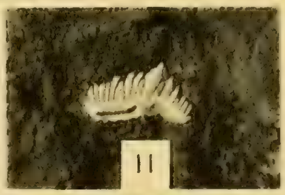
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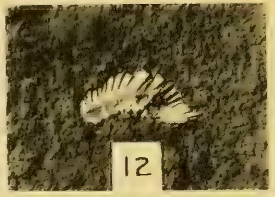
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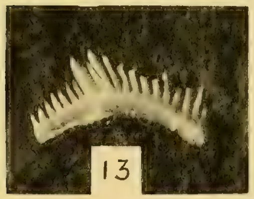
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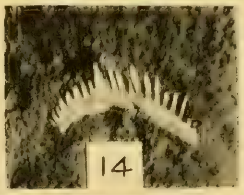
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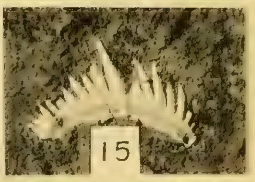
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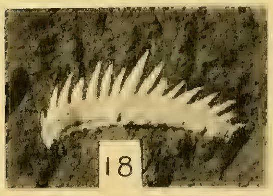
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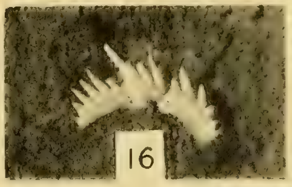
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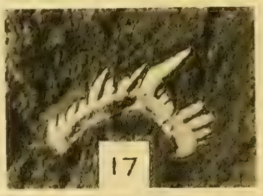
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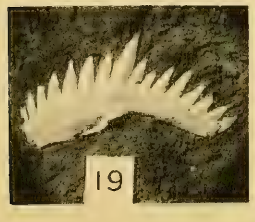
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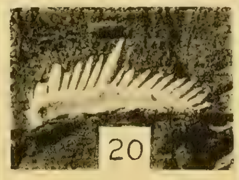
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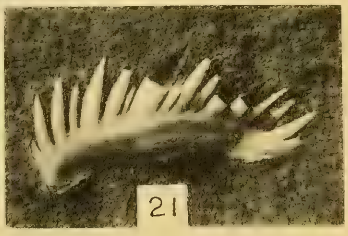
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PLATE III

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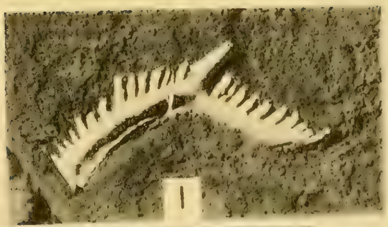
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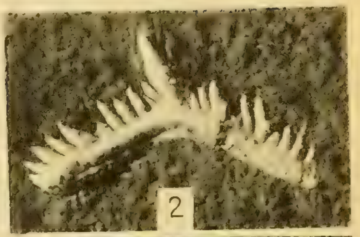
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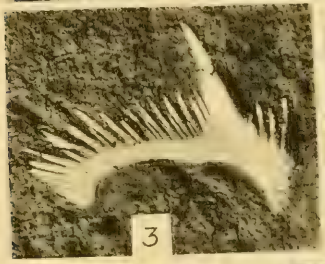
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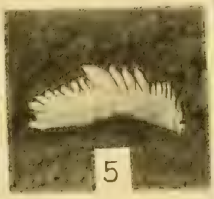
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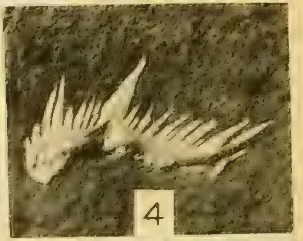
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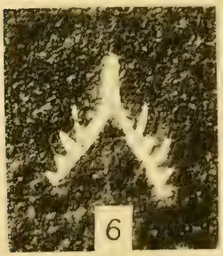
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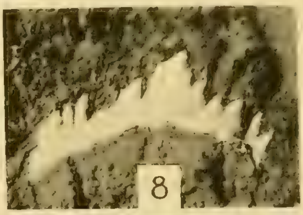
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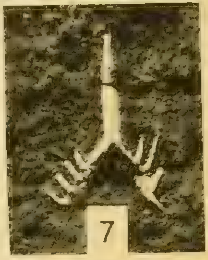
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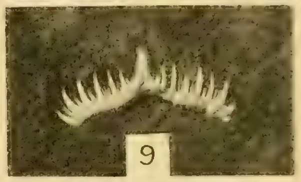
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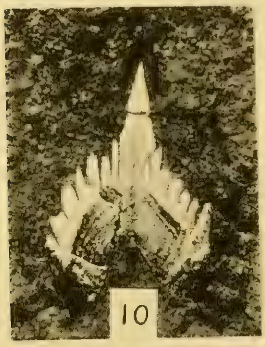
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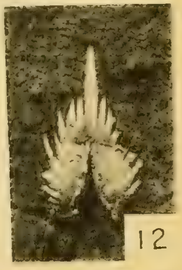
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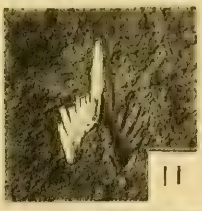
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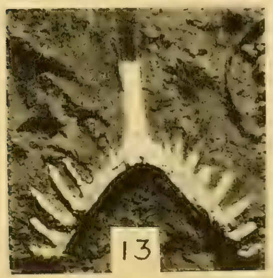
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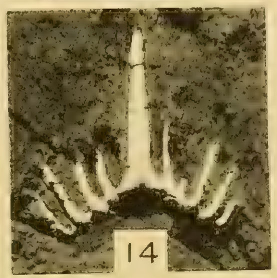
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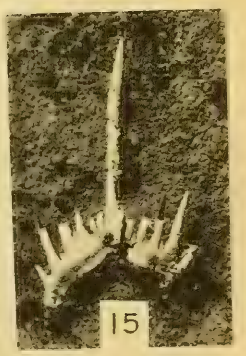
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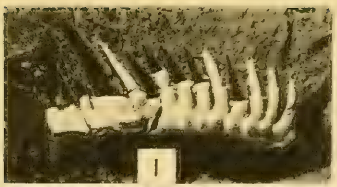
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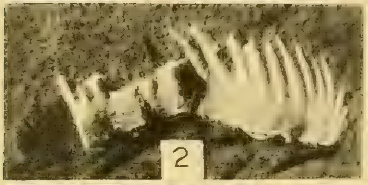
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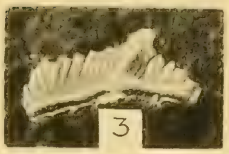
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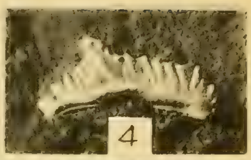
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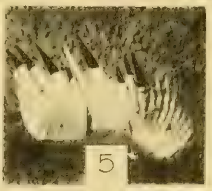
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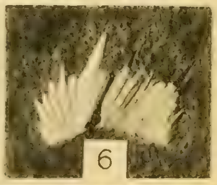
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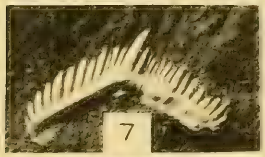
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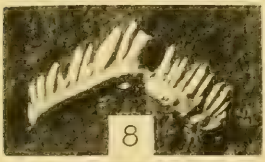
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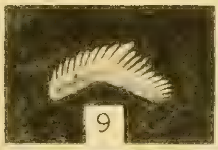
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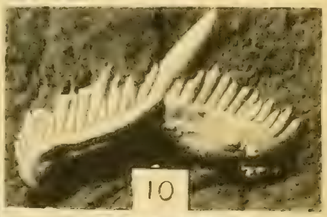
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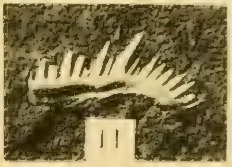
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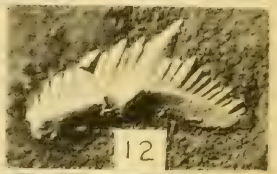
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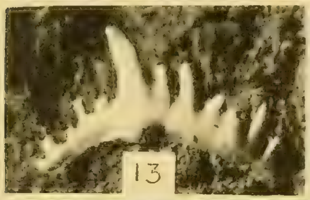
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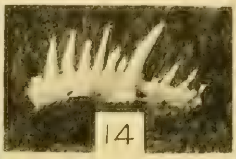
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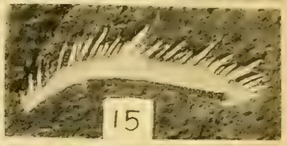
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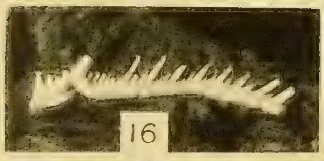
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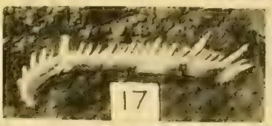
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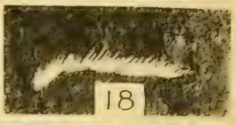
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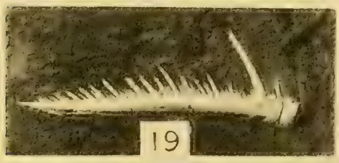
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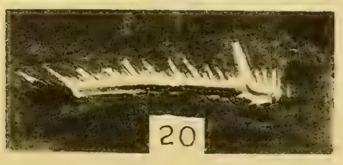
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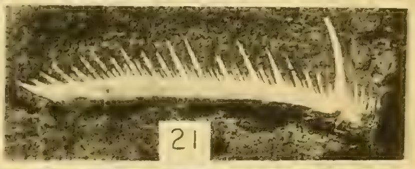
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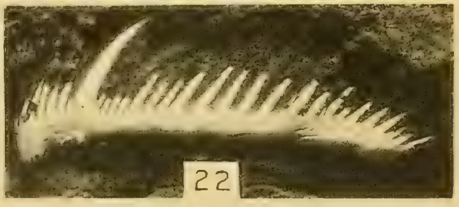
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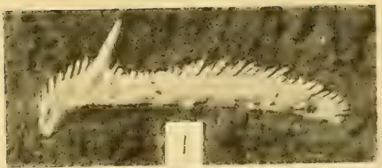
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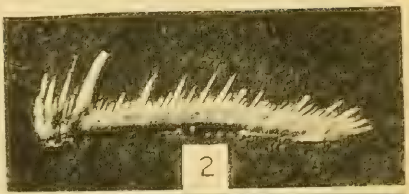
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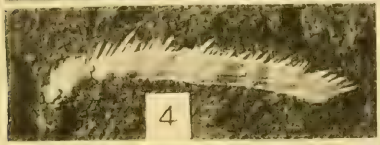
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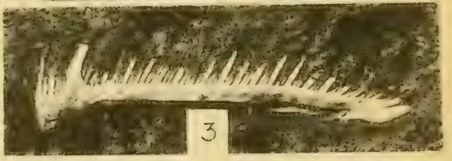
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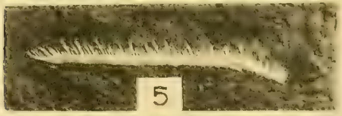
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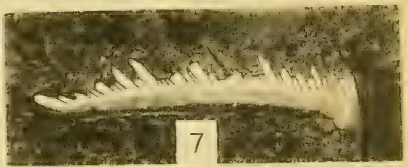
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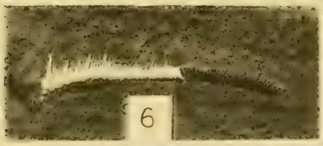
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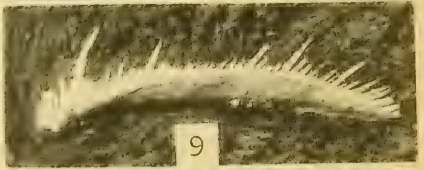
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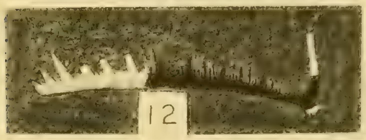
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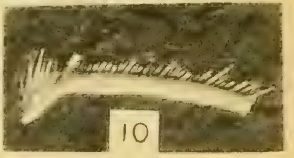
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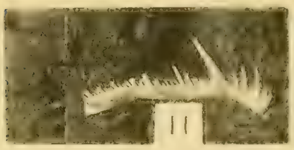
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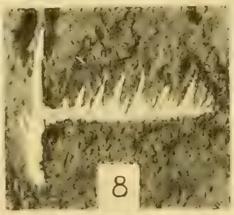
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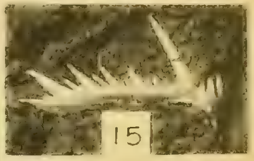
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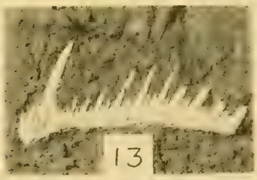
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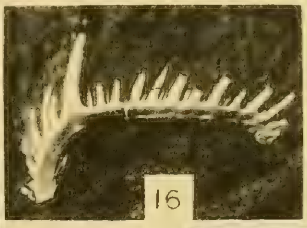
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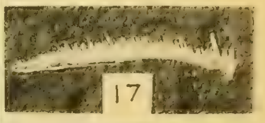
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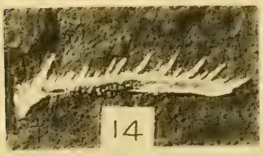
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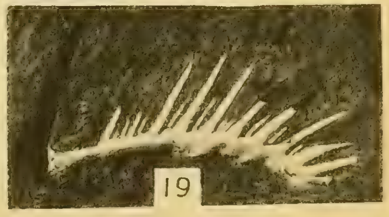
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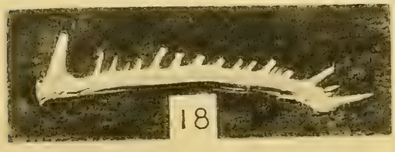
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PLATE VI

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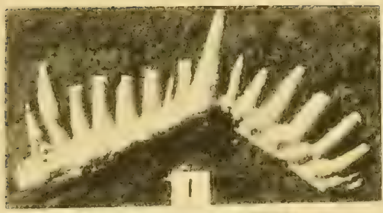
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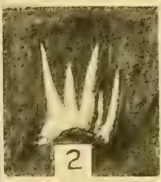
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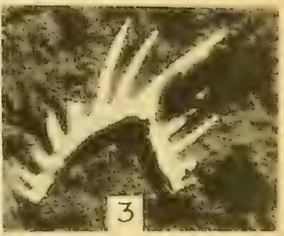
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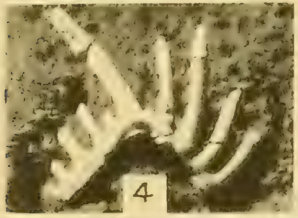
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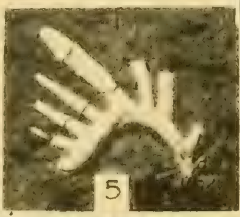
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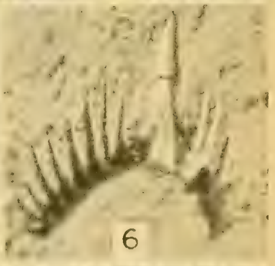
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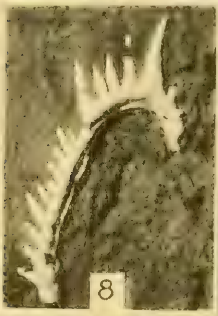
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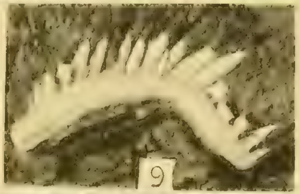
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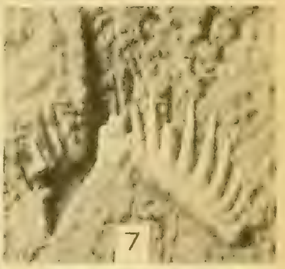
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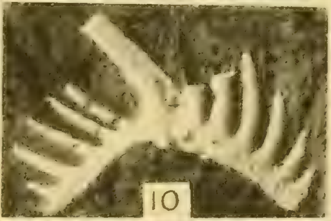
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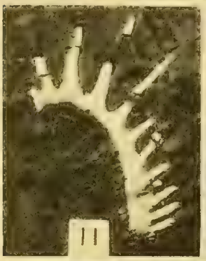
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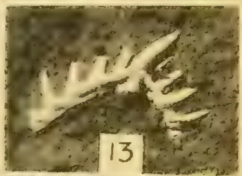
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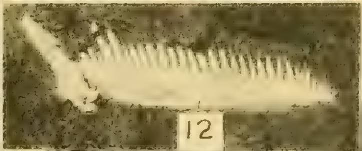
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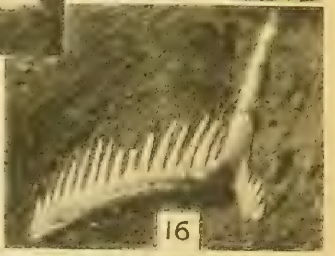
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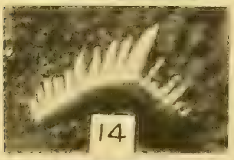
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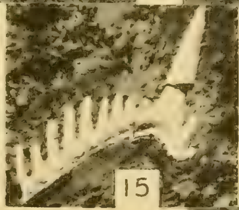
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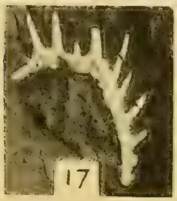
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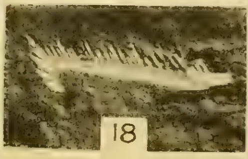
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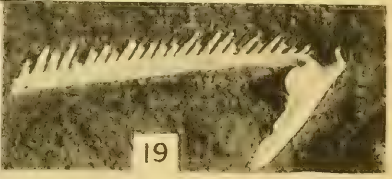
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PLATE VII

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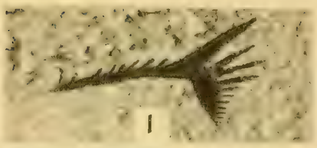
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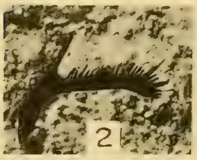
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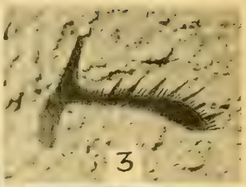
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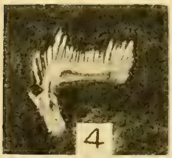
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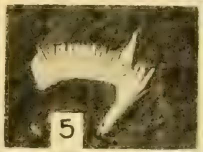
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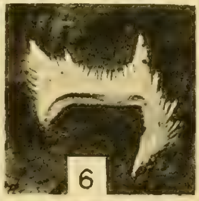
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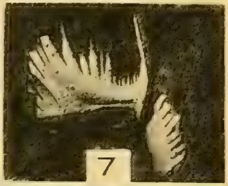
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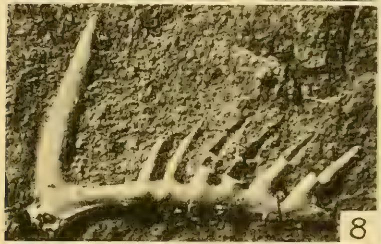
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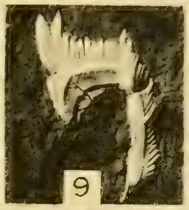
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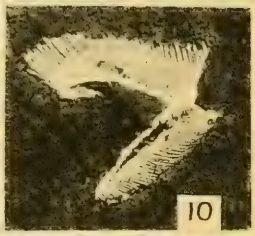
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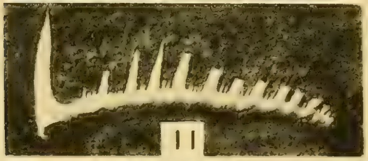
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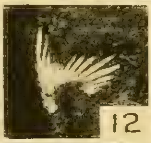
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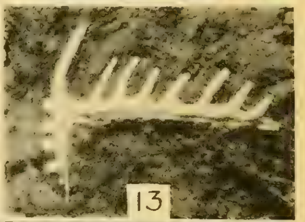
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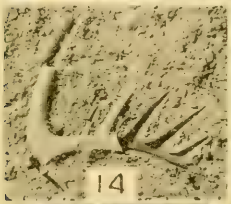
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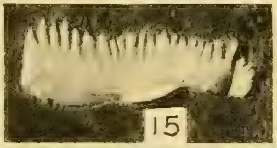
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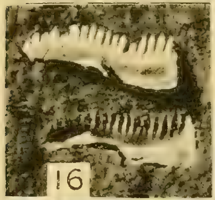
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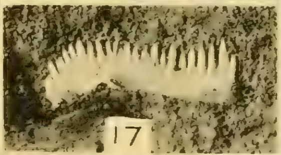
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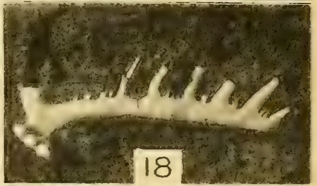
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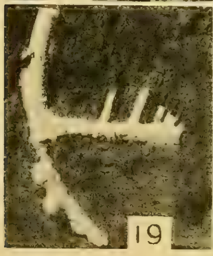
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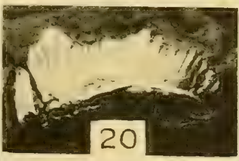
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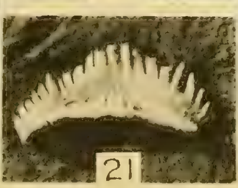
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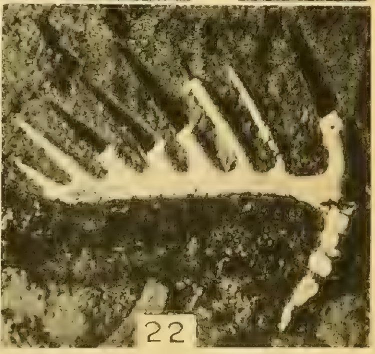
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PLATE VIII

(29) Plesitoype No. 1797, Locality 30, lower New Albany shale.

(30,31) Oral and lateral views of Plesiotype No. 2354, Locality 27, lower New Albany shale.

(32) Plesiotype No. 1946, Locality 28, lower New Albany shale.

33-35. **Polygnathus scapha**, new species x 15 ---------- 102

Oral, aboral and lateral views of Holotype No. 1910, upper New Albany shale, Locality 10.

36,37. **Polygnathus rotundiloba** Bryant x 15 ---------- 102

(36) Plesiotype No. 2363, Locality 32, lower New York shale.

(37) Plesiotype No. 2284, Locality 30, lower New Albany shale.

38. **Polygnathus ectypa**, new species x 15 ---------- 103

Holotype No. 1799, Locality 26, lower New Albany shale.

39-43. **Polygnathus plana**, new species x 15 ---------- 103

(39,40) Oral and aboral views of Paratype No. 1904, Locality 10, upper New Albany shale.

(41,42) Oral and aboral views of Holotype No. 1903, same locality.

(43) Oral view of another specimen from the same locality showing attrition around the margins of the plate.

44. **Polygnathus similis**, new species x 15 ---------- 104

Holotype No. 2285, Locality 20, middle New Albany shale.

45,46. **Polygnathus aspera**, new species x 15 ---------- 104

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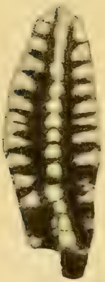
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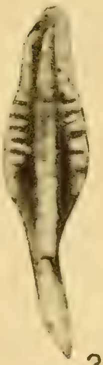
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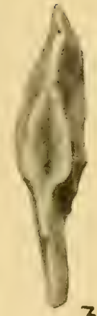
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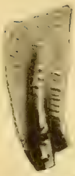
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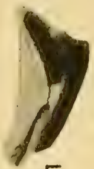
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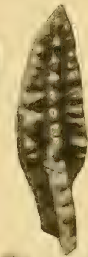
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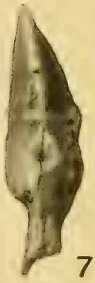
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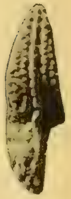
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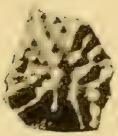
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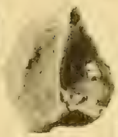
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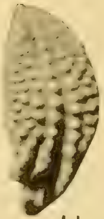
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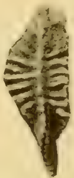
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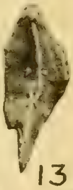
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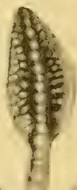
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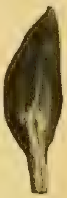
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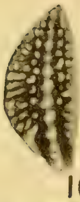
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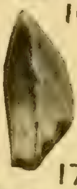
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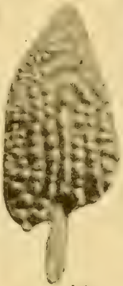
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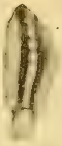
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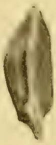
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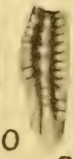
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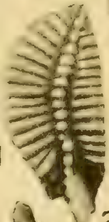
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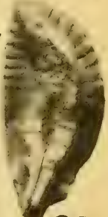
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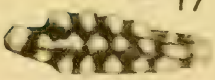
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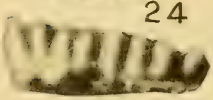
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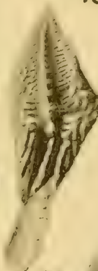
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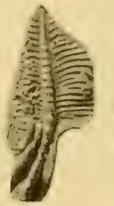
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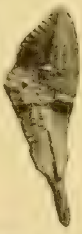
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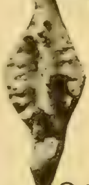
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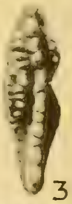
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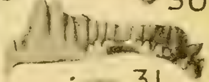
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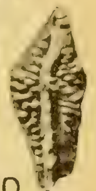
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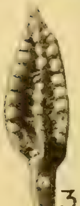
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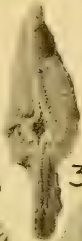
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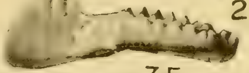
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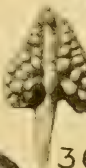
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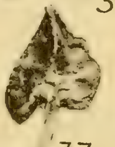
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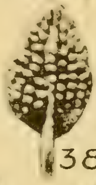
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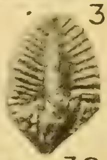
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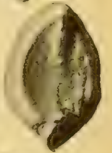
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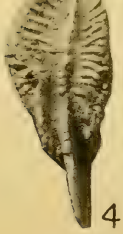
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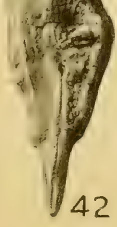
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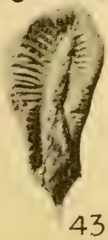
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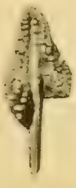
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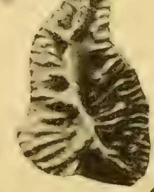
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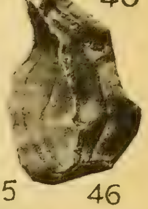
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PLATE IX

EXPLANATION OF PLATE 9

Figure Page

1, 2. **Palmatolepis pustulosa,** new species 106
(1) Paratype No. 2365, Locality 18, middle New Albany shale x 15.
(2) Holotype No. 2364, same locality x 30

3. **Palmatolepis** species x 30 107
Cat. No. 1801, Locality 30, lower New Albany shale.

4, 5. **Palmatolepis cymbula,** new species x 15 107
(4) Paratype No. 2366, Locality 18, middle New Albany shale.
(5) Holotype No. 2367, same locality.

6, 7. **Palmatolepis pectenifera,** new species x 15 107
Oral and aboral views of Holotype No. 1781, Locality 19, middle New Albany shale.

8-10. **Palmatolepis elongata** Holmes x 15 108
(8) Plesiotype No. 2282, Locality 20, middle New Albany shale.
(9) Plesiotype No. 2283, same locality.
(10) Plesiotype No. 1782, Locality 23, middle New Albany shale.

11-12. **Polygnathus** species x 15 105
Oral and aboral views of the same specimen. Cat. No. 2250, lower New Albany shale, Locality 26.

13-14. **Polygnathus** species x 15 105
Oral and aboral views of the same specimen. Cat. No. 1949, Locality 20, middle New Albany shale. Anterior end of the specimen broken off.

15-18. **Palmatolepis? inequalis** Holmes x 15 108
(15) Plesiotype No. 2344, Locality 20, middle New Albany shale. Tip of the lateral lobe broken off and appears shorter than it actually was.
(16) Plesiotype No. 2347, same locality.
(17) Plesiotype No. 2346, same locality.
(18) Plesiotype No. 2345, same locality.

19. **Polygnathus concentrica** Ulrich and Bassler x 12 105
Plesiotype No. 1943, Locality 20, middle New Albany shale.

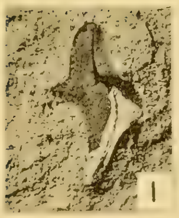
20. **Polygnathus gyralilineata** Holmes x 10 106
Plesiotype No. 1802, Locality 20, middle New Albany shale.

21-23. **Palmatolepis parlobata** Ulrich and Bassler x 15 109
(21) Plesiotype No. 2256, Locality 8, middle New Albany shale.
(22) Plesiotype No. 1783, Locality 20, middle New Albany shale.
(23) Plesiotype No. 1785, same locality.

24. **Palmatolepis minuta,** new species x 30 109
Holotype No. 1784, Locality 1, upper New Albany shale.

25. **Cladodus springeri** St. John and Worthen x 2 110
Plesiotype No. 2368, Locality 2, upper New Albany shale.

26,27. Supposed dermal plates of fish x 20
Cat. No. 1936, Locality 14, upper New Albany shale. These plates are frequently found associated with conodonts. The ones figured appear to be identical with those figured by Bassler, 1932, pl. 26, figs. 28, 29.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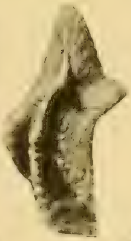
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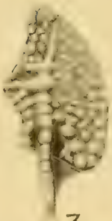
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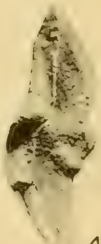
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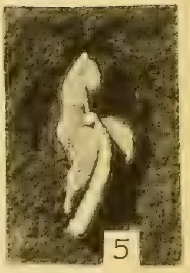
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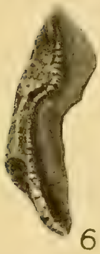
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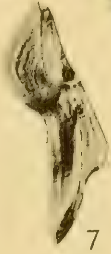
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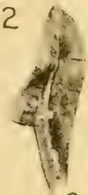
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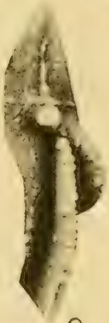
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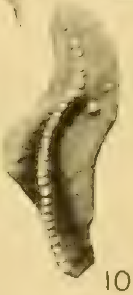
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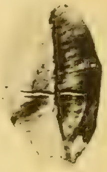
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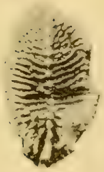
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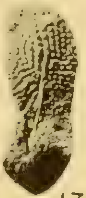
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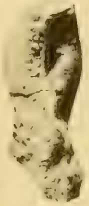
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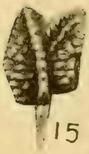
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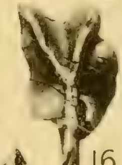
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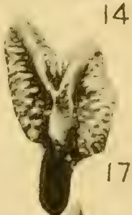
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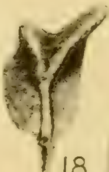
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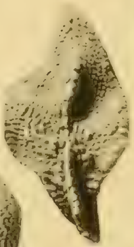
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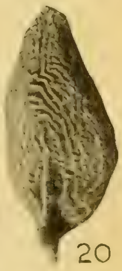
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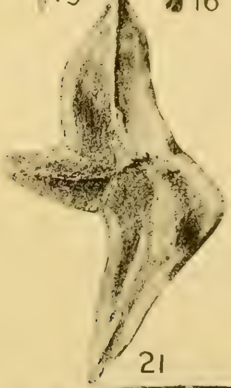
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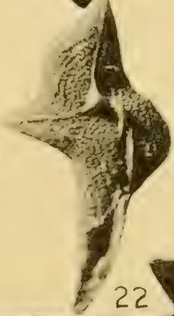
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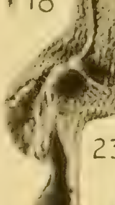
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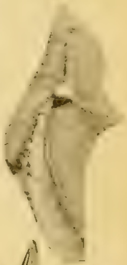
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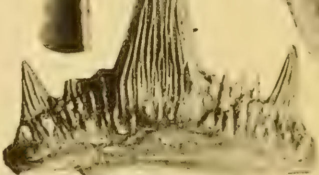
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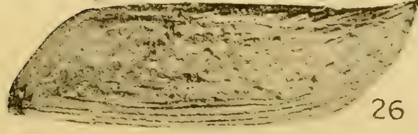
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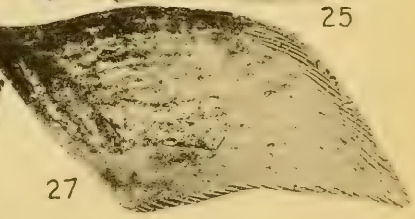
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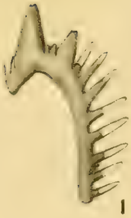
PLATE X

EXPLANATION OF PLATE 10

Figure		Page
1, 2.	**Lonchodina bicornis,** new species x 25 (1) Holotype No. 1867, Locality 1, upper New Albany shale. (2) Paratype No. 1866, same locality.	85
3.	**Lonchodina distans,** new species x 18 Holotype No. 2327, Locality 13, upper New Albany shale.	84
4.	**Lonchodina torta,** new species x 12 Holotype No. 1948, Locality 11, upper New Albany shale.	86
5.	**Angulodus walrathi** (Hibbard) x 25 Plesiotype No. 2339, Locality 1, upper New Albany shale.	77
6.	**Hibbardella? divergens,** new species x 36 Holotype No. 1837, Locality 13, upper New Albany shale.	81
7.	**Angulodus spissus,** new species x 18 Holotype No. 2286, Locality 20, middle New Albany shale.	78
8.	**Bryantodus planus,** new species x 25 Holotype No. 1932, Locality 20, upper New Albany shale.	75
9.	**Hindeodelloides** species x 49	49
10.	**Lonchodina prava,** new species x 18 Holotype No. 2297, Locality 20, middle New Albany shale.	86
11.	**Bryantodus aplatus,** new species x 18 Holotype No. 2329, Locality 26, lower New Albany shale.	76
12.	**Hibbardella angulata** (Hinde) x 18 Plesiotype No. 2293, Locality 20, middle New Albany shale.	78
13.	**Hindeodella jubata,** new species x 25 Holotype No. 2319, Locality 20, middle New Albany shale.	46
14.	**Hindeodelloides** species x 49 Cat. No. 2298, Locality 20, middle New Albany shale.	50
15.	**Angulodus demissus,** new species x 25 Holotype No. 2341, Locality 27, lower New Albany shale.	77
16.	**Hindeodella conidens,** new species x 18 Holotype No. 2260, Locality 9, upper New Albany shale.	47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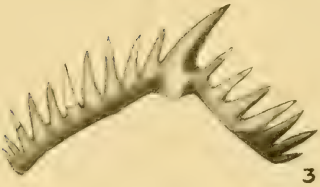
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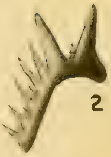
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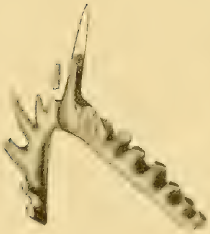
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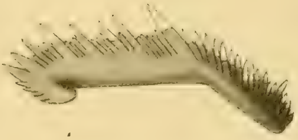
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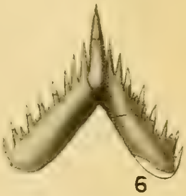
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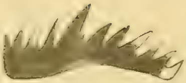
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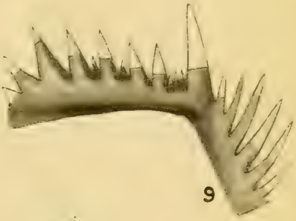
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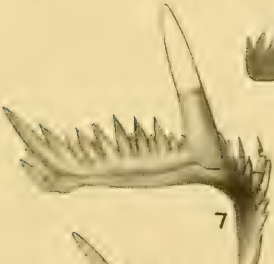
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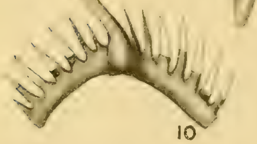
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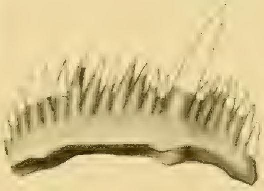
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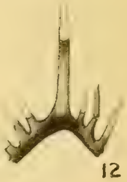
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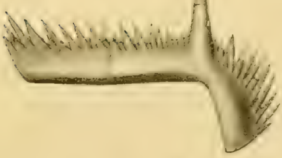
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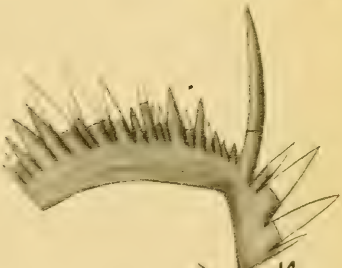
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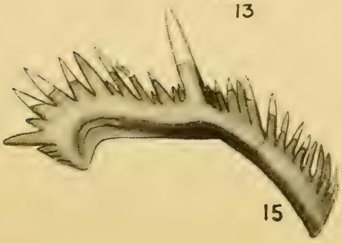
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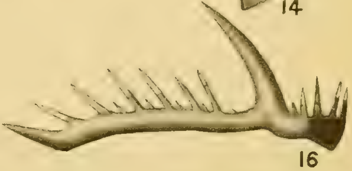
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PLATE XI

EXPLANATION OF PLATE 11

Figure		Page
1.	**Lonchodina? projecta** Ulrich and Bassler x 18 Plesiotype No. 1894, Locality 14, upper New Albany shale.	83
2.	**Lonchodina subsymmetrica** Ulrich and Bassler x 25 Plesiotype No. 2280, Locality 20, middle New Albany shale.	87
3.	**Palmatodella? paridens**, new species x 18 Holotype No. 1885, Locality 1, upper New Albany shale.	57
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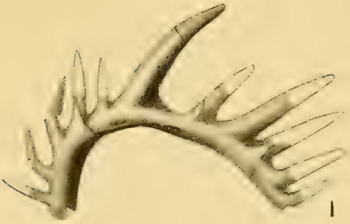
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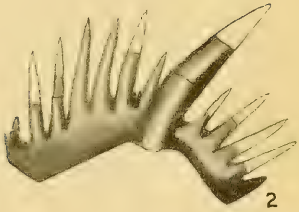
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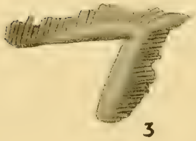
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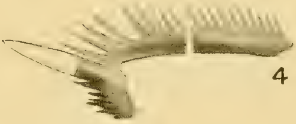
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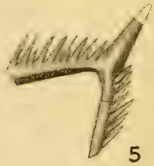
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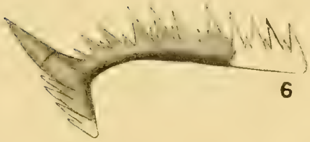
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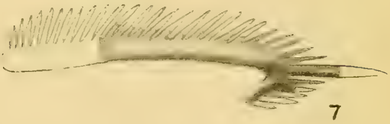
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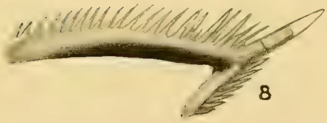
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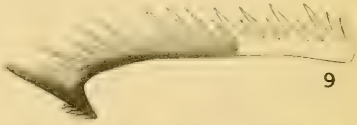
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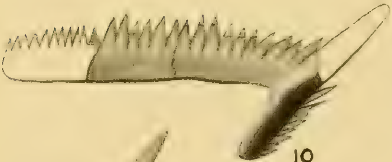
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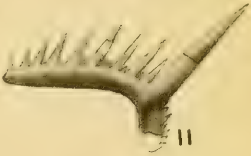
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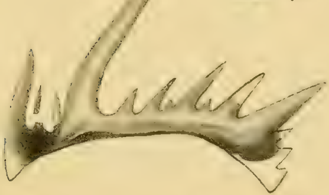
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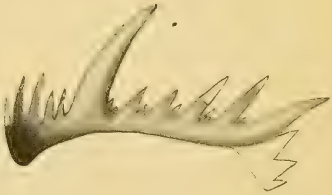
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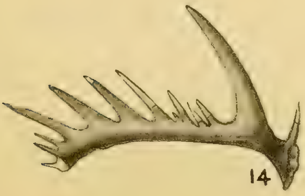
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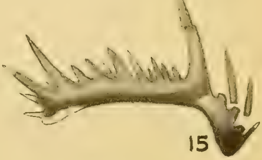
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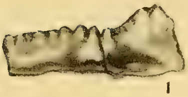
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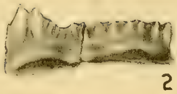
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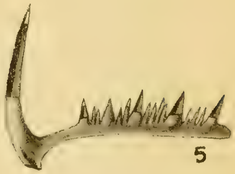
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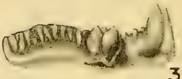
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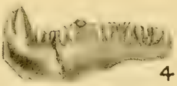
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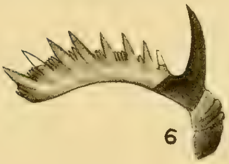
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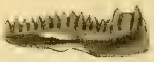
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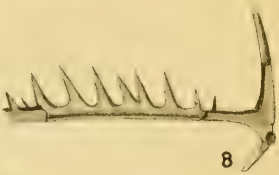
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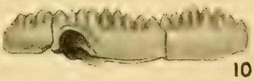
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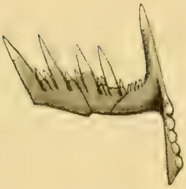
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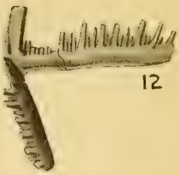
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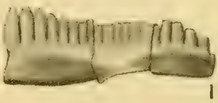
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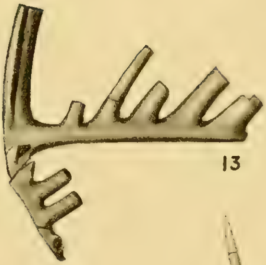
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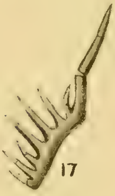
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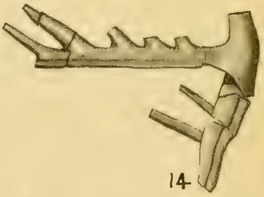
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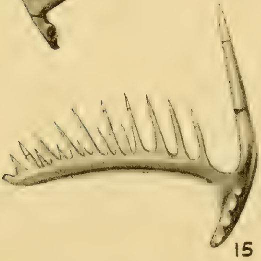
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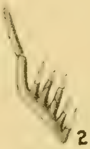
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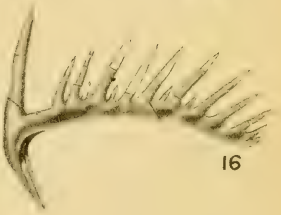
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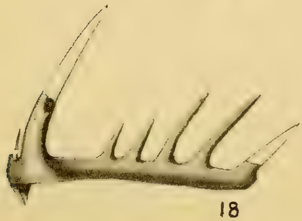
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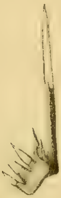
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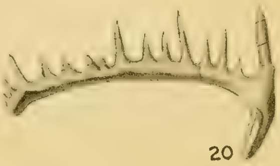
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